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Yield variations of six common bean (*Phaseolus vulgaris* L.) varieties under salt-affected soils in the Lower Shire Valley, Southern Malawi

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Performance of six released bean varieties was assessed under salt-affected soils at Nkhate and Masenjere irrigation schemes in Chikwawa and Nsanje districts, respectively in Malawi. The six varieties, Chimbamba, Napilira, Kalima, BCMV-B1, BCMV-B3 and Maluwa, were grown during the 2014/2015 growing season, employing a randomized complete block design. There were five replicates at each site, arranged in the upper, middle and lower sections which represented three blocks per site. In each replicate, six bean varieties were grown. Concentration of boron in the upper portions (leaves) served as an indicator of salt stress and possible tolerance mechanism to boron and chlorides. Yield was significantly reduced at one site (P<0.001) where salinity was the highest. There was a significant increase in soil and water salinity during the growing period.

Key words: Salinity, salinisation, Sodium adsorption ratio (SAR), electrical conductivity.

INTRODUCTION

Lower Shire Valley is a hot area receiving low rainfall of less than 1000 mm per annum compared to other parts of Malawi. Evaporation is higher than rainfall which increases the potential for soil salinisation in the area. Zewdu et al. (2017) demonstrated that continuous irrigation practices affect agricultural production potential through salt accumulation in irrigated fields. Salinisation can also be as a result of underground water containing different types of salts which may begin to rise and deposit some of the dissolved salts on the ground or left in the rooting zone (Ghassemi et al., 1995; Valema, 2008; Ali, 2010). In general, soil salinity can be created either from rock and mineral weathering or from buildup of salts as a result of irrigation under poor drainage (Chhabra, 2017).

In areas of arid and semiarid regions like the lower

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Shire Valley, soil salinisation is largely attributed to excessive evaporation and dissolution of parent rocks of quaternary alluvial origin and continous irrigation (Aredehey et al., 2018; Soliman and El-Shaieny, 2014; Smith-Carrington and Chilton, 1983).

Most of the research work in sub-Saharan Africa has focused on such biotic and abiotic factors as low and erratic rainfall, moisture stress, soil fertility, temperature extremes, pests and diseases, poor agronomic practices and lack of improved cultivars as factors affecting productivity of many agricultural and horticultural crops (Mwale, 2006; Chataika et al., 2009). Little work has been done to study quality of water and soil salinity as possible factors limiting crop production. However, most studies have revealed that salt stress is a major challenge in crop production especially in irrigated agriculture (Aredehey et al., 2018; Santos et al., 2018; Dixit, 2010; Yadav et al., 2011; Soliman and El-Shaieny, 2014).

There is no literature suggesting work on productivity of various crops under salt-affected soils in Malawi. According to studies carried out in regions with similar climatic conditions, yield of many sensitive crops including common bean is reduced at low salinity conditions (2.0 dS m^{-1}) in the soil (Ghassemi et al., 1995; Yadav et al., 2011). Studies in other parts of the Shire Valley have suggested that most of the areas have high salt content (FAO, 1970; Bath, 1980; Valema, 2008). Salinity of water in Shire River was reported to be 0.22 dS m^{-1} while in some irrigation wells at Tombondera was recorded at 0.37 dS m^{-1}. The area, therefore, presents a good setting to study production of crops sensitive to salinity.

The main objective of this study was to determine changes in salt levels in water and soils and to assess yield performance of six common bean varieties under salt-affected soils.

MATERIALS AND METHODS

Description of study area

The study was carried out at Nkhate Irrigation Scheme in Chikwawa District at16°9′ S and 134°56′ E, and Masenjere Irrigation Scheme in Nsanje District at 16°20′ S and 35°06′ E, in Southern Malawi.

Nkhate, at 80 m above sea level, is on the upper side of Shire River compared to Masenjere, which is 26 km further downriver at 57 m above sea level, along the eastern bank of the river. Nkhate has a gross area of 243 ha shared amongst 1,165 smallholder rice farmers, giving an average land holding size of 0.2 ha. The scheme is gravity-fed using water diverted from Nkhate River, a tributary to Shire River (Figure 1).

Masenjere has a total area of 125 ha with an average land holding size of 0.1 ha, and irrigation water is diverted from Masenjere River. The two irrigation schemes were purposely chosen, based on the long length of time they have been in operation, which is 33 years. Farmers grow rice, maize, sweet potato and common beans that are often grown in association with other crops. However, rice is the main crop at Nkhate Irrigation Scheme.

The two areas have distinct summer and winter seasons with an annual rainfall of less than 800 mm. Irrigation takes place during the winter season that spans May to August and into the hot season (September-October). During the 2014/2015 (October 2014 to March 2015) summer growing season, total evaporation was 2,429 mm against 747 mm of rainfall received. Pan evaporation in winter (April to August 2015), during conduct of this experiment, was 750 mm against 83 and 75 mm of rainfall at Nkhate and Masenjere, respectively.

Topography is generally flat, with slopes between 0 and 2%. Soils are provisionally classified as Entisols (FAO, 1970). Soil samples were taken at 0-15 and 15-30 cm depths for laboratory analysis.

Farmer selection

In each of the two schemes, plots were arranged from the water entry point (upper sections) to the bottom section. Three farmers were selected per scheme that represented blocks. Each farmer had six smaller plots in which six varieties were grown.

Bean genotypes evaluated

Six bean genotypes were grown in each farmer's plots. The six genotypes were Chimbamba (25-2 × 8-7); Napilira (CAL 143); Maluwa (CAL 113); BCMV-B1; BCMV-B3; and Kalima.

Treatments, experimental design and crop management

The field study used randomized complete block design (RCBD). Each of the three farmer's fields represented a block. There were five replicates at each site, arranged in the upper, middle and lower sections. In each replicate, six common bean varieties were grown.

Each farmer's field measured 50 m by 20 m (0.1 hectare). The field was divided into six plots measuring 16.0 m by 9.5 m with a 1.0 m space between the plots. Rows measuring 16.0 m were marked at 45 cm in each plot. Six bean varieties were grown, one seed per planting station spaced 15 cm. One seed was planted per station at 1 to 2 cm depth spaced 10 cm apart. Dwarf beans (Kalima, Maluwa, and Napilira) and a semi-dwarf (Chimbamba), were planted in two rows per ridge spaced 30 cm apart.

Fertilizer was applied at 100 kg per hectare rate applying 18g per 2 m of ridge length and weeding was done once weeds appear in the field using hoes except during flowering (Ministry of Agriculture and Food Security (MOAFS), 2012).

Data collection and analysis

Water samples were collected from the inlet of each scheme every two weeks during the study period and electrical conductivity (EC_w) was determined in dS m^{-1}. Exchangeable cations Na^+, Ca^{2+}, Mg^{2+}, K^+, and specific elements Cl^-, Na^+ and B in mg L^{-1}, were determined using the procedures outlined by Ryan et al. (2001). Sodium adsorption ratio (SAR) was derived mathematically using the following formula (Ghasemi et al., 1995):

$$SAR = \frac{Na^+}{\sqrt{\frac{(Ca + Mg)^{2+}}{2}}}$$

where all units are in mmol L^{-1} (Abrol et al., 1988).

Analysis of boron was done in the leaf margins of bean plants

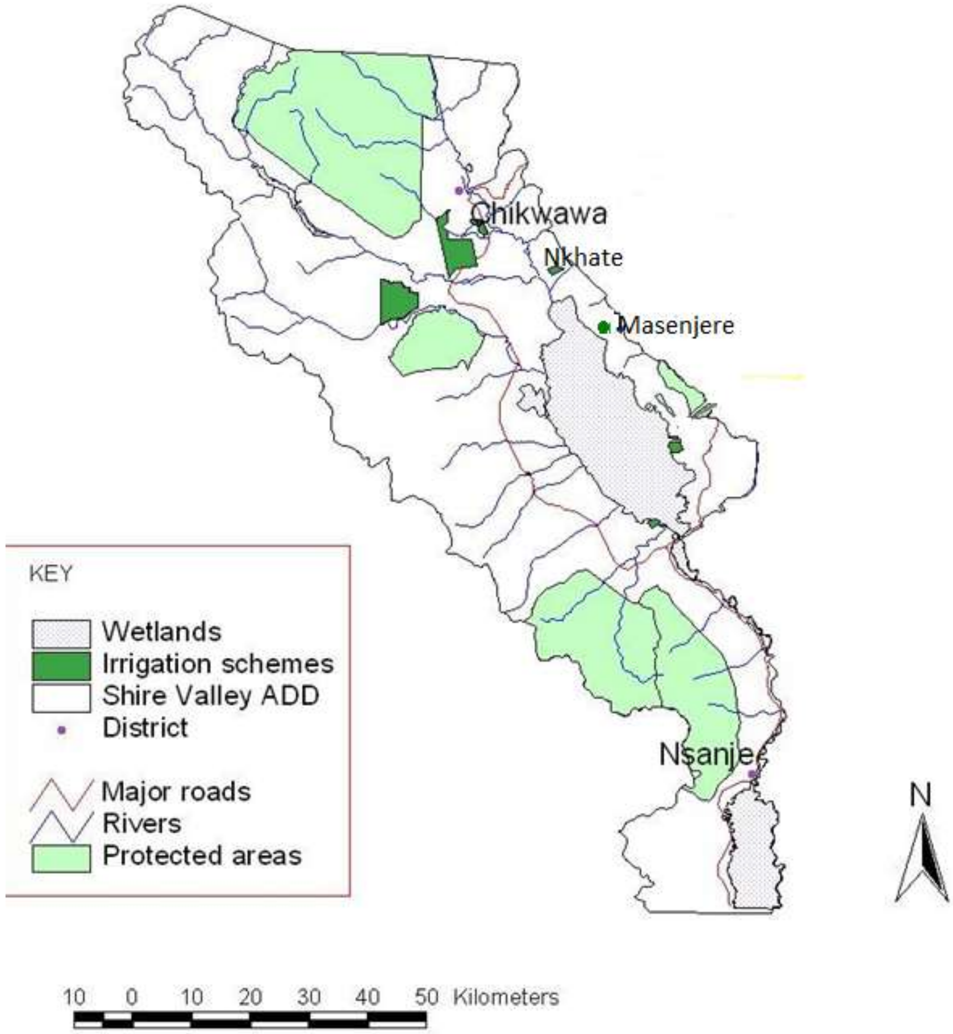

Figure 1. Map of the Shire Valley ADD showing the project sites.

using the hot water method as it is widely observed that boron concentrates in the margins (Kastori et al., 2008; Yadav et al., 2011). Agronomic data collected included: total number of plants per plot at harvest, days to flowering and maturity, number of pods and effective pods per plant, number of seeds per pod, 100-grain weight, and grain yield in kg ha^{-1} at a predetermined moisture content of 10%.

Data were analysed using GENSTAT 14th edition computer software package. Least Significant Difference (LSD) test at 5% probability was used to compare differences among treatment means (Steel et al., 1997). A linear regression relationship between yields with salinity was determined where slope of linear regression was considered a measure of sensitivity of yield to salinity.

RESULTS AND DISCUSSION

Soil characteristics of the study sites

The results in Table 1 showed less variation in both chemical and physical characteristics. Total N varied between 0.14 and 0.17% at Mesenjere and between 0.12 and 0.14% at Nkhate. The normal range of total N in soils for plant growth is 0.1 to 0.15% meaning that in the two schemes total N was adequate for crop production. Available P varied from 30 to 60 mg kg^{-1} at Masenjere and 40 to 80 mg kg^{-1} and was within sufficient range for crop production. However, K ranged from 1700 to 1900 mg kg^{-1} at Masenjere and between 900 and 1100 mg kg^{-1} at Nkhate. A concentration of potassium above 800 mg kg^{-1} is considered excessive for most agricultural crops.

Water salinity changes

The study recorded both temporal and spatial variations in water salinity (Table 2). Differences in water salinity were significant ($P<0.05$). In each scheme water salinity changed significantly during the growing period. It showed increasing trend from planting to harvesting (Table 2).

Irrigation water in Nkhate irrigation scheme was more

Table 1. Soil characteristics at Nkhate and Masenjere Irrigation Schemes.

Scheme	Section	pH	OM (%)	N (%)	P (mg kg^{-1})	K (mg kg^{-1})	Soil Type
Nkhate	Upper	6.9	2.75	0.14	60	900	Sandy clay loam
	Middle	6.7	2.48	0.13	40	1000	Sandy clay loam
	Bottom	6.8	2.24	0.12	80	1100	Clay loam
	Mean	6.8	2.49	0.13	60	1000	-
Masenjere	Upper	6.5	3.42	0.17	40	1900	Clay loam
	Middle	6.6	2.75	0.14	60	1700	Clay loam
	Bottom	6.9	2.75	0.14	30	1800	Clay loam
	Mean	6.7	2.97	0.15	40	1800	-

Table 2. Temporal changes of irrigation water and soil salinity of Nkhate and Masenjere irrigation schemes measured as electrical conductivity (EC, dS m^{-1}).

Month	Irrigation water salinity (EC, dS m^{-1})			
	Nkhate	Masenjere	Mean	SE
June	0.324	0.204	0.264	0.060±
July	0.727	0.313	0.520	0.207±
August	1.248	0.912	1.080	0.168±
Mean	0.776	0.674	0.621	-

saline than that used in Masenjere ($P<0.05$). Average water salinity in Nkhate during common bean germination was 0.324 dS m^{-1} as compared to 0.204 dS m^{-1} during the same period at Masenjere Irrigation Scheme.

The differences in water salinity status could be a result of the differences in the source of the water or rivers, Nkhate and Masenjere. The rivers originate from different areas in the Thyolo-Chikhwawa Escapement. These areas are far from each other, and they may have different parent materials with different mineral compositions (FAO, 1970; Monjerezi and Ngongondo, 2012). This would explain the differences in the measured water electrical conductivities (EC_w).

Aredehey et al. (2018) and Abrol et al. (1988) argued that the main source of all salts in the soil is the primary minerals in the exposed layer of the earth's crust. During the process of chemical weathering involving hydrolysis, hydration, solution, oxidation and carbonation, the salt constituents are gradually released into the soil and made soluble. The salts are then transported away from their source of origin through surface or groundwater streams. Salts in the groundwater stream are gradually concentrated as the water with dissolved salts moves from the more humid to the less humid and relatively arid areas. Similarly, water may be originating from aquifers. If this is the case, the water tends to have a lot of dissolved salts which will be deposited into the river.

As the water with dissolved soluble salts moves from the more humid to the arid regions, the water becomes concentrated with the salts and the concentration may become high enough to result in precipitation of salts of low solubility (Abrol et al., 1988). Chemical constituents of water may undergo further changes through processes of exchange, adsorption and differential mobility with the net result of increasing the concentration in respect of chloride and sodium ions in the underground water and also in the soil.

Furthermore, in both locations the rivers are used for domestic activities including washing clothes. Members of the communities wash their laundry in the rivers which may also increase the chances of increased salt content in water in the two schemes. Literature suggests that while detergents can increase plant growth in the short term, they tend to damage soil quality in the long run. They argue that most conventional laundry detergents have high salt levels. The salts are carried into the soil by the water which builds up over time. While the immediate effect of the salts is to increase plant growth, it also results in increased salinity in the long term.

During the flowering phase (July), average water salinity in Nkhate River had increased to 0.727 dS m^{-1} and by the time beans were maturing and ready for harvesting, water salinity had risen to 1.248 dS m^{-1}. The salinity figures for June concur with the water salinity figures reported by FAO (1970). FAO (1970) reported water salinity of 0.22, 0.15 and 0.37 dS m^{-1} for Shire River, Tangadzi River and Tombondera irrigation well in Chikwawa, respectively.

Temporal increase in water conductivity has been reported in other river ecosystems. UNESCO (1970) reported higher water salinity in Medjerda River in Tunisia between May and November. Ayers and Westcot (1985) also reported significant increase in water salinity in Wadi Shebelle River in Ethiopia and Somalia from late April and early June and from October and November. During these periods, river water salinity ranged from EC_w = 0.75 to 2.0 dS m^{-1} and occasionally exceeding EC_w = 2.5 dS m^{-1}. This was against the normal EC_w of less than 0.5 dS m^{-1} observed in the river when there was no rain. The researchers concluded that the sudden rise in water salinity was due to high rainfall during the said periods which caused runoff from Ogadan plateau which is of marine formation and feeds Wadi Shebelle River. Runoff transports the salts into the river. This explanation cannot be applied in this research because during the period when salinity was high, there was no heavy rainfall to cause runoff to transport salts into the river. Rather, it is the opposite. Other literature like Ayers and Westcot (1985) argue that water salinity is inversely related to flow and dilution due to runoff in the rainy or snowmelt, keeping the salt concentration low.

Though the eastern part of Ethiopia which borders Somalia has some geological similarities with the study sites, there are also some differences which could explain the differences in causes of salinity changes. The eastern part of Ethiopia, which boarders Somalia has, among others rocks, Cenozoic continental and marine sediments and Cenozoic volcanic and sedimentary rocks of the East African Rift Valley (Geological Survey of Ethiopia, 1996). It also has quaternary alluvial and lacustrine deposits. In comparison, the large part of the study sites consists of quaternary alluvium (Smith-Carington and Chilton, 1983).

Increasing water salinity in both rivers correlated with the increasing temperatures towards the end of the growing season. There is a general understanding that water and soil salinity tend to be higher towards the end of summer when temperatures are high compared to cooler months. This is due to higher evapotranspiration and weathering of parent rock materials in the river sources. During the study period, there was rise in atmospheric demand as evidenced by highly negative estimated net-precipitation. This means there was increasing evaporation which could have resulted in high concentration of salts in the river Nkhate as water volume in the rivers dropped. This argument is also supported by Ayers and Westcot (1985) who reported similar degradation pattern of surface water quality in Wadi River in Yemen. Their work revealed an inverse relationship between water salinity and water volume. Many rivers including Rio Grande River and San Joaquin River in USA and Euphrates and Tigris Rivers in Iraq also show the same trend in water salinity within a growing season.

Research has concluded that in most irrigated fields, water with electrical conductivity less than 0.7 dS m^{-1} or 450 mg/L of total dissolved solids can be used for irrigation without major concerns of affecting crop water availability (Ayers and Westcot, 1985). Common bean, however, is very sensitive to salinity during the early phases from germination to flowering phase. In Masenjere Irrigation Scheme, salinity during the two stages could not cause yield reduction as supported by Table 4.

Soil salinity

Initial soil salinity during germination phase (June) at Nkhate was 0.472 dS m^{-1} rising to 2.041 dS m^{-1} by the time the plants had started flowering (July) and to 3.56 dS m^{-1} during harvest period in August (Table 3). This phenomenon subjected beans to different soil salinity levels within a short period.

It was also observed that during flowering and maturity phases, the highest EC_e values were recorded in the bottom sections followed by middle section while the lowest values were recorded in the upper sections of the scheme (Figure 2).

At germination, however, salinity was lowest at the bottom section. This could mean that soil salinity was largely influenced by water used for irrigation (Ayers and Westcot, 1985; Oztekin and Tuzel, 2011). The high level of soil salinity in this section after irrigation was due to the combined effect of irrigation water and capillary rise of salts from the ground water table.

It has been reported that soil salinity levels later in the growing season tend to change in response to irrigation and drying cycles because of crop water use (Ayers and Westcot, 1985; Ali, 2010). Salinity micro-variation patterns in soils also become more pronounced later in the crop season. Seasonal soil salinity is normally found to be the highest following crop moisture extraction after the last irrigation event.

In irrigated fields, salts originate from high saline, water table or from salts in the applied water (Ali, 2010; Ayers and Westcot, 1985). It is the effect of salts from the irrigation water which is having more influence on the salinity fluctuations in Nkhate Irrigation Scheme. According to Ayers and Westcot (1985), salinity problems encountered in irrigated agriculture are mostly associated with an uncontrolled water table (Ali, 2010) within 1 to 2 m of the ground surface. Water rises into the active root zone by capillarity in soils with a shallow water table, and, if the water table contains salts, this becomes a continual source of salts to the root zone as water is used by the crop or evaporates at the soil surface. Salinization from this source can be rapid in irrigated areas in hot climates where portions of the land remain fallow for extended periods.

Sodium adsorption ratio (SAR)

On average, Masenjere had 26.4 mg L^{-1} of Na and in Nkhate concentration was 27.5 mg L^{-1}. These findings, however, were not significantly different. Amounts of Ca^{2+}

Table 3. Spatial and temporal variations of soil salinity in Nkhate and Masenjere irrigation schemes.

Period	Soil salinity (EC, dS m^{-1})			
	Nkhate	Masenjere	Mean	SE
June	0.472	0.015	0.247	0.0179±
July	2.041	0.557	1.297	0.0697±
August	3.560	1.140	2.356	0.095±
Mean	2.024	0.557	1.300	-

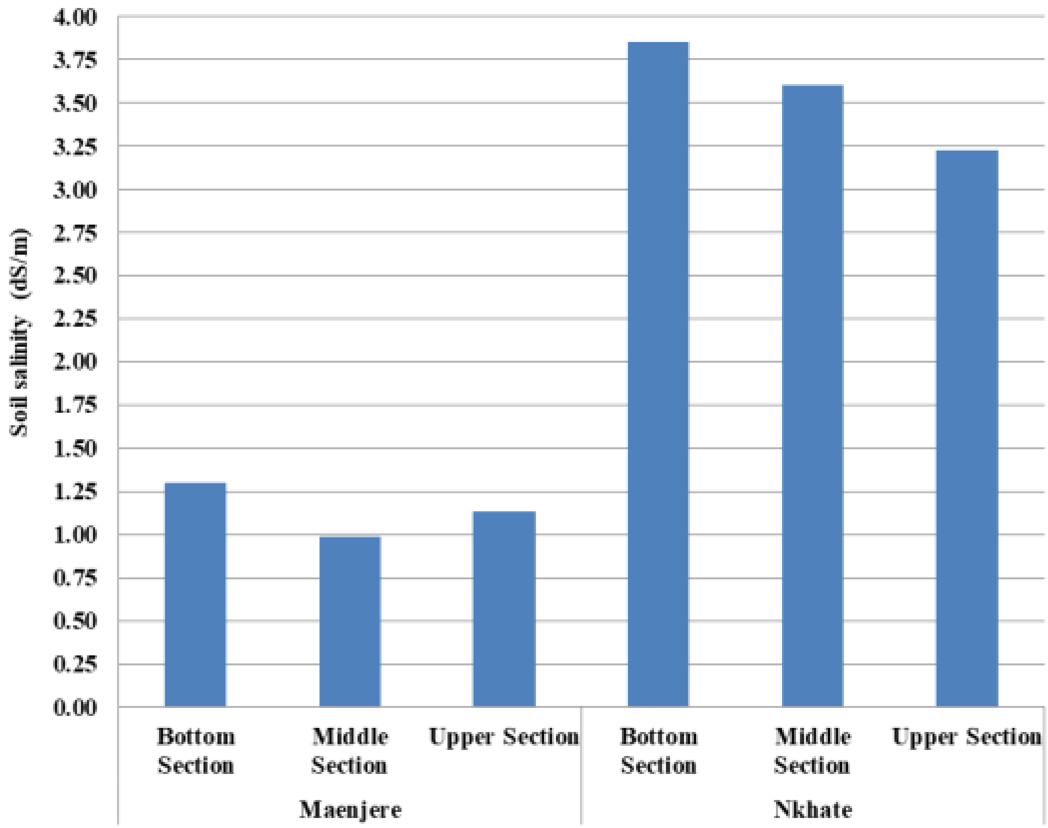

Figure 2. Spatial variation of soil salinity in Nkhate and Masenjere irrigation schemes.

and Mg^{2+} in the two locations were lower, 7.4 and 6.2 me L^{-1} for Ca^{2+} and Mg^{2+}, respectively in Masenjere and 9.04 me L^{-1} Ca^{2+} and 7.66 me L^{-1} Mg^{2+} in Nkhate. In all blocks the amount of the Ca and Mg were lower than that of sodium (Table 5).

Estimated SAR was relatively higher in Masenjere than in Nkhate. Though the soil paste electrical conductivity values were below the critical values for saline soils, the SAR in all the blocks across the locations were lower than 15, which is characteristic of saline soils (Abrol et al., 1988). Soil salinity level of all plots measured in Nkhate Irrigation Scheme is capable of affecting bean growth and development since beans are very sensitive to salinity and yield can be reduced at EC_e less than 2 dS m^{-1} (Gama et al., 2007; Gutierrez et al., 2009).

Soils with SAR lower than 13, ESP lower than 15 and EC_e greater than 4 dS m^{-1} are classified as saline soils. Such soils tend to be flocculated, and as such soils have a weak soil structure though it is not a major concern as compared to sodic soils (Ali, 2010; Horneck et al., 2007). When the soil SAR is high there tends to be a problem of decreased water infiltration. In this study, however, the SAR poses medium risk to crop growth. There is a small chance of affecting crop production in the long run. This is not a major problem in such soils because such soils contain high concentrations of Ca and Mg.

High levels of B and Cl^- in the soils were recorded during the study period (Table 4). Differences were

Table 4. Soil chemical characteristics in Masenjere and Nkhate Smallholder Irrigation Schemes.

Site	Section	Saturation paste extract concentration					SAR
		(mg kg^{-1})		(me L^{-1})			
		B	Cl^-	Ca^{2+}	Mg^{2+}	Na^+	
Nkhate	Upper	0.99	48.88	7.46	6.16	28.14	10.78
	Middle	1.20	64.75	8.84	8.99	27.92	9.43
	Bottom	1.14	50.82	10.81	7.82	26.52	8.78
	Mean	1.11	54.82	9.04	7.66	27.53	9.66
Masenjere	Upper	0.77	24.52	6.02	5.32	22.23	9.26
	Middle	0.52	23.32	7.50	5.50	31.62	12.54
	Bottom	0.38	25.13	8.58	7.85	25.21	8.92
	Mean	0.56	24.32	7.37	6.22	26.35	10.24

significant (P<0.01) for both trace elements. Concentration of Cl^- was very high in Nkhate. Concentrations of Cl^- were, however, not significantly different among blocks within sites. Mean Cl^- concentrations for the two sites were 24.3 and 54.8 me/L for Masenjere and Nkhate Irrigation Scheme, respectively, and these differed significantly (P<0.05).

According to Ayers and Westcot (1985) chloride ions affect sensitive crops like beans at lower levels between 4 and 10 me L^{-1}. Observed differences in the concentration of Cl^- could be attributed to sources of the water used for irrigation in the two schemes, as the schemes use water from different rivers which originate from different places with different types of parent rock materials. The rocks are expected to release different types and amount of minerals upon weathering. The source of these rivers may explain these differences. Geology of the study sites indicates that they have alluvial deposits but this alone cannot explain the observed differences.

Yield and yield components

Kalima performed better than the other five varieties in Nkhate Irrigation Scheme where salinity levels were higer, yielding 207 kg ha^{-1} followed by BCMV-B3 and Maluwa at 187 and 175 kg ha^{-1}, respectively. Chimbamba yielded the lowest at this site (Table 5). The performance of each variety was, however, below potential yield of more than 1500 kg ha^{-1} (Ministry of Agriculture and Food Security (MOAFS), 2012). Kalima, Napilira and Maluwa can yield up to 2000 kg ha^{-1}. Analysis of covariance indicated significant differences in yield of the varieties. Overall, Maluwa performed poorly than the rest of the varieties.

The research found a correlation (R^2=0.627) between yield and salinity in the two schemes. Where salinity was low, yield was the highest. From germination to flowering period, soil salinity ranged from 0.36 to 2.16 dS m^{-1}. Ayers and Westcot (1985) and Abrol et al. (1988) explained that beans are sensitive to salinity and bean yield is reduced by up to 10% when soil salinity is just slightly above 1.0 dS m^{-1}. Between germination and flowering mean soil salinity in the bottom section of Nkhate Irrigation Scheme was over 1.0 dS m^{-1}. It can therefore be concluded that low bean yields in the bottom sections were affected by high salinity during the critical periods. The results also concur with work by Ghassemi-Golezani et al. (2012) who reported decreasing yield of pinto beans due to increasing salinity level. The extent of reduction is however dependent on the level of severity and variety.

Similar results were observed by Tavakkoli et al. (2010) who recorded reduced growth and yield of faba beans in salt affected soils. They argued that the poor yield was as a result of Cl^- and Na toxicity. They concluded that excessive Cl^- ions in the soil reduce photosynthesis when these ions are taken up by plants. This could also be the case with beans at Nkhate irrigation scheme where Cl^- concentration was relatively higher than in Masenjere irrigation scheme (Table 4).

Amounts of boron in both locations were higher than the recommended value of 0.15 mg kg^{-1} (Ryan et al., 2001). Plant roots absorb more boron which would normally be toxic to the bean plants at concentrations above 0.15 mg kg^{-1}. According to Ryan et al. (2001) common beans are sensitive to B concentration in soils and their yield is reduced drastically when extractable B is between 0.5 and 0.75 mg L^{-1} (Abrol et al., 1988). It was observed that soils in Nkhate had higher amount of extractable B (1.11 mg/kg) as compared to Masenjere (0.56 mg/kg). The highest B amount was recorded at Nkhate (1.20 mg kg^{-1}) and while the lowest amount of 0.38 mg B kg^{-1} was recorded at Masenjere (Table 4).

Yield components

Number of effective pods, seeds per pod and number of nodes also decreased from the upper to the bottom part of the scheme (Tables 6 and 7). Nkhate irrigation scheme

Table 5. Mean yields of bean entries at Nkhate and Masenjere Irrigation Schemes.

Variety	Location	Upper	Middle	Bottom	Mean
BCMV-B1	Nkhate	98.63	271.97	127.26	165.95
	Masenjere	413.63	531.68	363.54	436.28
BCMV-B3	Nkhate	180.91	268.99	112.24	187.38
	Masenjere	508.08	544.25	350.67	467.67
Chimbamba	Nkhate	210.07	112.03	130.66	150.92
	Masenjere	453.94	528.13	414.35	434.15
Kalima	Nkhate	233.14	288.69	99.40	207.08
	Masenjere	302.29	563.08	456.37	440.58
Maluwa	Nkhate	17.03	267.94	81.43	122.13
	Masenjere	414.79	527.68	319.50	367.15
Napilira	Nkhate	142.56	189.72	146.62	159.63
	Masenjere	476.32	525.52	479.83	493.89
Mean		287.616	356.387	256.823	300.28

Table 6. Agronomic characteristics of bean varieties at Nkhate Irrigation Scheme.

Variety	Seed size (g/100 seeds)	Seeds/pod	Effective pods/plant	Pod length (cm)	Nodes/Plant
Chimbamba	37.40	4.47	5.3	11.7	5.0
Napilira	30.53	4.87	4.3	11.4	6.1
Kalima	39.30	4.93	3.0	8.9	5.7
BCMV-B1	24.17	5.53	2.7	10.2	5.4
BCMV-B3	30.43	4.27	2.0	7.0	7.0
Maluwa	35.43	5.40	2.3	9.6	6.0
Mean	32.88	4.91	3.3	9.8	5.9
CV	10.8	33.7	45.8	22.7	16.1
LSD	6.5	2.5	2.7	4.03	2.26

Table 7. Agronomic characteristics of bean varieties at Masenjere Irrigation Scheme.

Bean entry	Seed size (g/100 seeds)	Seeds/pod	Effective pods/plant	Pod length (cm)	Nodes/Plant
Chimbamba	50.3	4.5	11.2	13.1	8.5
Napilira	45.8	4.9	9.9	12.9	7.1
Kalima	52.9	4.9	8.7	12.5	7.3
BCMV-B1	33.8	5.5	13.7	14.2	5.4
BCMV-B3	42.8	4.3	11.3	10.7	9.5
Maluwa	47.2	5.4	10.2	12.0	6.7
Mean	45.5	4.9	10.8	12.6	7.4
CV	6.2	15.2	26.1	11.4	16.1
LSD	5.1	1.4	5.2	3.2	-

showed less number of effective pods with an average of 2.5 effective pods while in Masenjere there were 9.0 effective pods per plant. As supported by Katerji et al. (1992) and Ghassemi-Golezani et al. (2012), low seed-weight was due to higher salinity at Nkhate as compared to that in Masenjere Irrigation Scheme. This also contributed to low yield in Nkhate irrigation scheme resulting in higher osmotic stress. Tavakkoli et al. (2010) on the other hand argued that low yield attributed reduced yield of faba bean under salt stress to high sodium, chloride and boron content. This research therefore does not rule out such a possibility.

Conclusion

The study has concluded that all the six common bean entries used in the study were affected by the salt content in the soil. However, Kalima and BCMV-B3 were more tolerant to salinity than the other four varieties though the results were not significantly different. It also concluded that water salinity increased in Nkhate and Masenjere due to increased temperature. Soil salinity in the two schemes was largely attributed to quality of water applied in the two schemes and increased evapotranspiration. High salinity in the bottom sections revealed that salinity was also a result of salt rise by capillarity.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Abrol IP, Yadaf JSP, Massaaud FI (1988). Salt-affected soils and their management. Food and Agriculture Organisation. Rome: FAO.

Ali M (2010). Fundamentals of irrigation and on-farm water management (Vol. 1). New York: Springer. doi:10.1007/978-1-4419-6335-2

Aredehey G, Libsekal H, Brhane M, Welde K, Giday A (2018). Top-soil salinity mapping using geostatistical approach in the agricultural landscape of Timuga irrigation scheme, South Tigray, Ethiopia. Cogent Food and Agriculture 4:514959. doi:https://doi.org/10.1080/23311932.2018.1514959

Ayers R, Westcot D (1985). Water quality for agriculture Rev. 1. FAO, Rome. FAO. Rome: FAO.

Bath AH (1980). Hydrogeochemistry in groundwater development: report on an advisory visit to Malawi. British Geological Survey. England: British Geological Survey.

Chataika B, Bokosi J, Kwapata M, Chirwa R, Mwale V, Mnyenyembe P, Myers J (2009). Performance of parental genotypes and inheritance of Angular Leaf Spot (Phaesariopsis griseola) resistance in common bean (Phaseolus vulgaris). African Journal of Biotechnology 9(28):4398-4406.

Chhabra R (2017). Soil salinity and water quality. New Delhi, India. Oxford & IBH publishing Co. Ltd.

Dixit C (2010). Impact of spatially variable soil salinity on crop physiological properties, soil water content and yield of wheat in a semi arid environment. Australasian Journal of Agricultural Engineering 1:93-100.

Food and Agriculture Organisation of the United Nations (FAO) (1970). Lockwood Soil Survey of the Lower Shire Valley Report. Food and Agriculture Organisation of the United Nations. Rome: FAO. Retrieved April 02, 2015.

Gama P, Inanaga S, Tanaka K, Nakazawa R (2007). Physiological response of common bean (Phaseolus vulgaris L) seedlings to salinity stress. African Journal of Biotechnology 62:79-88.

Ghassemi F, Jakeman A, Nix HA (1995). Salinisation of land and water resources. Wallingford: CABI.

Ghassemi-Golezani K, Zehtab-Salmasi S, Nikpour-Rashidabad N (2012). Effect of salinity on yield and yield components of pinto bean cultivars. International Journal of Plant. Animal and Environmental Sciences 2(2):47-51.

Gutierrez M, Estrada J, Gonzalez MT (2009). Differences in salt tolerance between Phaseolus vulgaris and Phaseolus coccineus cultivars. International Journal of Agricultural Research 4(9):270-278.

Kastori R, Maskovic I, Klaljevic-Balalic, Kabiljski B (2008). Physiological and genetic basis of plants tolerance to excess boron. Proceedings of the National Academy of Sciences 114:41-51.

Katerji N, Van Hoorn J, Hamdy A, Bouzid N, El-Sayed Marous S, Mastrorilli M (1992). Effect of salinity on water stress, growth, and yield of broad beans. Agricultural Water Management 21:107-117.

Ministry of Agriculture and Food Security (MOAFS) (2012). Guide to crop production and natural resource management in Malawi. Lilongwe: Agricultural Communications Branch.

Monjerezi M, Ngongondo C (2012). Quality of groundwater resiources in Chikhwawa, Lower Shire Valley, Malawi. SpringerLink 4(1):35-53. Retrieved from http://link.springer.com/article/10.1007/

Mwale VM (2006). Performance and stability of advanced bean (Phaseolus vulgaris) lines under two systems of on-farm evaluation in three agro-ecological zones in Malawi. University of Malawi (Bunda College of Agriculture). Lilongwe: Bunda College of Agriculture.

Oztekin GB, Tuzel Y (2011). Salinity response of some tomato rootstocks at seedling stage. African Journal of Agricultural Research 6(20):4726-4735.

Santos A, da Silveira J, Bonifacio A, Rodrigues A, Figueiredo M (2018). Antioxidant response of cowpea co-inoculated with plant growth-promoting bacteria under salt stress. Brazilian Journal of Microbiology, pp. 513-521.

Smith-Carrington A, Chilton P (1983). Groundwater resources of Malawi. Department of Lands, Valuation and Water. Lilongwe: Department of Lands, Valuation and Water. https://www.ircwash.org/sites/default/files/824MW83-4021.pdf

Soliman WS, El-Shaieny AHA (2014). Effect of saline water on germination and early growth stage of five Apiaceae species. African Journal of Agricultural Research 9(7):713-719.

Steel RD, Torrie J, Dickey D (1997). Principkes and procedures of statistics: A biometrical approach (3rd ed.). New York: McGraw Hill.

Tavakkoli E, Rengasamy P, Macdonald G (2010). High concentration of Na+ and Cl- ions in soil solution have tremendous detrimental effects on growth of faba bean under salinity stress. Journal of Experimental Botany 61(15):4449-4459.

Valema J (2008). Soil salinisation on the floodplains of Lower Shire Valley. Thesis. Netherlands: University of Twente.

Yadav S, Irfan M, Ahmad A, Hayat S (2011). Causes of salinity and plant manifestations to salt stress: A review. Journal of Environmental Biology 32:667-685.

Zewdu S, Suryabhagavan K, Balakrishnan M (2017). Geo-spatial approach for soil salinity mapping in Sego Irrigation Farm, South Ethiopia. Journal of the Saudi Society of Agricultural Sciences 16(1):16-24.