International Journal of Research in Agriculture and Forestry
Volume 3, Issue 2,February 2016, PP 6-10
ISSN 2394-5907 (Print) & ISSN 2394-5915 (Online)

Phytoremediation as a Solution to Salinity Problems in French bean Production in Migori County, Kenya

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ABSTRACT

French bean is a crop with high potential as an income earner. The study site, Migori county has the right conditions for its production except for saline soil in some areas. Soil salinity is one of the major problems in crop production in recent times. Mulching has been used as a conventional method of mitigating salinity stress though its effect is only short-lived. A modern approach of using halophytes as pytoremediators has of late been accepted. Field experiments with three French bean varieties, three treatments and three replications were conducted in Migori county during short and long rain seasons between 2014 and 2015. *Portulaca oleracea* was used as the phytoremediator. The objective was to evaluate how French bean yields were influenced by phytoremediation and mulching. The experiment was laid out in a 3x3x3 factorial in Randomized Complete Block Design (RCBD) and means separated by Duncan's Multiple Range Test (DMRT) at 5% level of significance. Plots with *P. oleracea* intercrop yielded more than the other two treatments. Since *P. oleracea* treatment enhanced realization of higher yields, it is recommended that farmers adopt the technology in production of French bean or any other crop sensitive to salinity.

Keywords: Phytoremediation, conventional, French bean, Mulching, Halophyte

INTRODUCTION

Soil salinity is one of the major constraints in crop production especially for salt-sensitive crops. Several strategies have been put in place so as to mitigate the effects of salinity amongst them being use of halophytes in the process of phytoremediation. Phyoremediation is a biological approach proving the efficiency of Na^+ -hyperaccumulating plants to desalinize the soil on which they are cultivated, especially in arid and semi-arid regions, where low precipitations and inappropriate irrigation systems are unable to leach salts from the rhizosphere. Soil phytodesalination is based on the capacity of some halophytes to accumulate enormous sodium quantities in their shoots (Rabhi *et al*., 2010).

MATERIALS & METHODS

Study Site

The experiment was conducted in Nyatike, Migori County which lies at an altitude of 1135- 1350 m above sea level in South-western Kenya. Temperatures range between 19.3 – 30^{0}C. Rainfall is erratic but can be categorized into short and long rain seasons at a range of 600-1200 mm p.a. Soils are mostly clay but saline soils also occur (MOA, 2008).

Three varieties of French bean (*Samantha, Monel and Star),* were grown as the test crop. The varieties were chosen for their availability in the market, farmer acceptability and marketability of the pods. In this study, two salinity mitigation methods together with a control were used in three replicates. The experiment was carried out in two seasons: short rain season of 2014 and long rain season of 2015. Each plot size was 1.5 m x1 m.

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Data Collection and Parameters Measured

Soil characterization at the start and end of the experiment

French bean yield:

Pod weight

Pod length

Pod width

Statistical Analysis

The data obtained were subjected to analysis of variance (ANOVA). The mean differences were separated by Duncan's Multiple Range Test (DMRT) at 0.05 level of significance.

RESULTS

Soil Characterization

Results of soil characterization carried out on soils from the study site before and after the experiments are as shown in Table 1 below. At the end of the experiment, electrical conductivity (Ec), pH, sodium and chloride levels were lower. Nitrate levels remained unchanged.

Table1. *Soil characteristics at the start and at the end of the experiment*

Character	Ec (dSm^{-1})	pH	Nitrate (mg/ l)	Sodium (mg/ l)	Chloride (mg/ l)
Start	3.90	7.60	25.00	36.00	42.00
End	3.52	7.40	25.00	31.00	33.67

Effects of Salinity Mitigation Method and Variety on Pod Length

In season 1, there were significant differences in salinity mitigation methods used on pod weight (Table 2). Generally, in season 2 there were higher means in all the three treatments as compared to season 1. The general mean length in season 2 was higher than in season 1 at 10.77 and 10.39 cm respectively. Varietal differences did not have any influence on pod length in either season.

Table2.

Parameter	Treatment	SEASON 1				SEASON 2			
		V1	V2	V3	Mean	V1	V2	V3	Mean
Pod length (cm)	Control	8.50	7.20	10.50	8.73**b**	7.33	10.63	8.70	8.89**b**
	Mulching	11.20	10.63	11.77	11.20**a**	11.43	12.43	10.83	7.67**a**
	Purslane	9.73	12.27	11.73	11.24**a**	11.20	12.40	11.33	11.64**a**
	$DMRT_{0.05}$	2.01				1.80			
	Mean	9.81**a**	10.03**a**	11.33**a**		9.99**a**	11.82**a**	10.89**a**	
	$DMRT_{0.05}$	3.49				3.11			
	CV (%)	19.40				16.81			
Pod width (cm)	Control	0.68	0.53	0.60	0.61**b**	0.62	0.76	0.61	0.66**b**
	Mulching	0.69	0.60	0.73	0.67**ab**	0.71	0.64	0.78	0.71**b**
	Purslane	0.82	0.74	0.73	0.76**a**	0.77	0.83	0.84	0.81**a**
	$DMRT_{0.05}$	0.11				0.10			
	Mean	0.73**a**	0.62**a**	0.69**a**		0.70**a**	0.74**a**	0.74**a**	
	$DMRT_{0.05}$	0.18				0.18			
	CV (%)	15.51				14.11			
Pod weight (gm^{-2})	Control	1989	1604	1991	1861**b**	2063	1998	2005	2022**c**
	Mulching	2286	2017	2249	2184**b**	2628	2700	2376	2568**b**
	Purslane	3496	2912	3137	3182**a**	4007	3287	3395	3563**a**
	$DMRT_{0.05}$	432				436			
	Mean	2590**a**	2178**a**	2459**a**		2899**a**	2662**a**	2592**a**	
	$DMRT_{0.05}$	956				752			
	CV (%)	18.13				15.97			

Key: *Means within a row or column with different letters are significantly different ($p \leq 0.05$).*

Effects of Salinity Mitigation Method and Variety on Pod Width

From the analysed results, salinity mitigation methods had significant differences in both seasons. As presented in Table 2, it is clear that in season 1, control had the lowest mean whereas purslane had the highest (0.61 and 0.76 cm, respectively). In season 2, the control had the lowest mean though it was higher than in season 1. There was no significant difference between control and mulching in season 2. Treatment with purslane yielded the highest mean in both seasons. There was no significant difference between the varieties used.

Effects of Salinity Mitigation Method and Variety on Pod Weight (g m-2)

There were significant differences among the salinity mitigation methods under investigation in this experiment in both seasons as shown in Table 2. In season 1, intercropping French bean with purslane with a mean of 3182 g m^{-2} was significantly different from both mulching and control with means of 2184g m^{-2} and 1861 g m^{-2}, respectively. In season 2, all the three treatments differed significantly from one another. The control had a mean of 2022 g m^{-2}, mulching had 2568 g m^{-2} and intercropping with purslane had the highest mean of 3563g $m^{-2.}$

Generally, mean pod weight was higher in the second season at 2718 g m^{-2} compared to the first season when it was 2408 g m^{-2}. Variety had no significant effect on pod weight of French beans in either season. There was no significant difference in the green house experiment (Table 2).

Capacity of Purslane in Reducing Soil Salinity

Results obtained from the experiment show that salinity levels were generally higher in season 1 than in season 2 (Table 2) in all the treatments. Plots intercropped with purslane had significantly lower salinity levels at the end of the second season. Green house results did not show any significance (Table 2).

Table3. *Salinity levels (dSm^{-1}) at the beginning and at the end of the experiment*

Season 1	Control	Mulching	Purslane	Mean	DMRT	CV (%)
Start	3.90	3.90	3.90			
End	3.88a	3.61b	3.30c	3.59	0.09	5.48
Season 2	**Control**	**Mulching**	**Purslane**	**Mean**	**DMRT**	**CV (%)**
Start	3.88	3.72	3.35			
End	3.86a	3.53b	3.25c	3.54	0.21	0.59

Key. *Means within a column with different letters are significantly different ($p \leq 0.05$).*

DISCUSSION

Soil Characterization

Soils in the study area were found to be high in salinity (Table 1), a factor that hindered French bean growth and yield due to the fact that the crop is sensitive to salinity. At the end of the experiment, electrical conductivity, pH, sodium and nitrogen levels were lowered. This is attributed to the fact that by its ion uptake from the soil, purslane lowers soil ionic concentration. Nitrate levels were not significantly affected because French beans fix nitrogen and thus replenish that which is used up.

Effects of Salinity Mitigation Method and Variety on Pod Length

The higher pod length means in mulched and purslane - intercropped plots can be attributed to the cooler temperatures accorded by the covering act and the salinity mitigation achieved (Table 2). The low measurements in the control were as a result of the exposed soil loosing much more water through evapo-transpiration leading to salt deposition around the root zone. There was a general improvement in pod lengths in season 2 due to the fact that even during off-season, promiscuous purslane and mulch continued with their mitigation effects. Thus crops grown on plots with salinity mitigation put in place did not have to use much of their resources in countering the adverse effects of salinity leading to larger pods.

The control recorded the least pod length. In the control, the mean pod length recorded was the least. This is because the plots had higher salinity. These results are supported by Jamil and Rha, (2007) who concluded that in saline environments, photosynthetic activity decreases leading to reduced plant growth, leaf area and chlorophyll content which affects crop performance in different growth stages.

Effects of Salinity Mitigation Method and Variety on Pod Width

The findings of the experiment (Table 2) showed that in both seasons, purslane plots had higher pod width than mulched and control plots and this was attributed to the salinity effect on the plots. The results are in agreement with several studies that showed that the chlorophyll contents significantly decreased under elevated salt stress, as they are sensitive to salt exposure and a reduction in chlorophyll levels due to salt stress has been reported in several plants, such as pea (Ahmad and Jhon, 2005), wheat (Ashraf *et al*., 2008) and rice (Anuradha and Rao, 2003).

Effects of Salinity Mitigation Method and Variety on Pod Weight

As shown in Table 2, there were significant differences among salinity mitigation methods in both seasons. Plots that had salinity mitigation methods practiced suffered less harm from effects that are attributed to salinity. The results are in agreement with Duzdemir *et al*., (2009) who worked on pea and found out that increased soil salinity resulted in significant decreases in either number of pods and pod dry weights or number of seeds and dry seed weights. Sultana *et al*., (2000) found that the reduction in photosynthesis in the salinized plants led to low concentrations of assimilates in the leaves so that low levels and poor translocation of assimilates from the source reduced grain dry matter. This also contributed to a difference in pod weighs in different treatments.

Plots that had purslane intercrop showed higher pod weights than the rest due to the fact that in its normal growth, purslane took up salts from the soil and lowered the salinity of the soil to the level that was conducive for French bean growth.

Under salinity stress in the control, plants recorded low yields because of adverse effects of salinity. The plants generally had poor yields since they were not operating at their maximum potential. Reduced photosynthesis under salinity is attributed to stomata closure leading to a reduction of intercellular carbon dioxide concentration (Stepien and Klobus, 2006). Results of an experiment by Taffouo *et al*., (2010) indicate that salinity reduces the content of photosynthetic pigments in treated plants. With reduced photosynthesis, there isn't enough photosynthesized material to be stored in the pods thus low yields.

Effect of Purslane in Reducing Soil Salinity

Purslane has the capacity of reducing soil salinity to a rhizospheric level as shown in Table 3. Purslane forms a dense mat covering the soil and preventing the emergence of other seedlings. Its aggressive and prostrate growth has suggested that purslane can be used as living mulch intercropped with a row crop, for example broccoli, whose yield was not reduced (Ellis *et al*., 2000).

In tomato, it was observed that Na^+ concentration in leaves was reduced by 36% when grown with purslane, while fruit yield increased by 33% (Graifenberg *et al*., 2003). Purslane removed 210 kg/ha of Cl^- and 65 kg/ha of Na when cultivated at 6.5 dSm^{-1} as an intercrop in fruit orchards during one growing season (Kilic *et al.*, 2008).

The effects of consociation with halophytic plants are in all encouraging, since a general trend towards a mitigation of the condition of stress in the tomato plants can be detected (Albaho and Green 2000). Already Graifenberg *et al*., (2003) observed optimal results for purslane in terms of salt stress reduction.

CONCLUSION

The results of the study show that purslane has the capacity of reducing soil salinity to levels that can be tolerated by sensitive crops thus increasing their yields.

RECOMMENDATIONS

The study recommends use of purslane in control of salinity especially in the semi arid areas where salinity levels are high if sustainable food production is to be realized.

ACKNOWLEDGEMENT

The authors appreciate the support provided by National Commission for Science, Technology and Innovation (NACOSTI) and University of Eldoret in carrying out this research.

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