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Managing sesbania decomposition with urea and different tillage techniques in salt affected soil

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Abstract

Green manuring is an integral component of sustainable agriculture and is an effective strategy in rehabilitation of salt affected soils. Also selection of tillage implements to be utilized under salt affected soils is very important for the seed bed preparation. For this purpose a study was carried outat Soil Salinity Research Institute, Pindi Bhattian, Pakistan to develop the best technique for decomposition of sesbania with urea fertilizer and tillage implements in saline sodicsoil. Twourea fertilizer levels i.e. control(no urea) and 40 kg ha^{-1} and three different tillage implements cultivator, disc harrow and rotavator were used insplit plot arrangement. Tillage implements were allocated in main plots and urea levels in sub plots keeping sub-plot. A salt affected field {EC_e= 6.50 (d Sm^{-1}), pH_s= 8.90 and SAR = 45.70 (m mol L^{-1})$^{1/2}$ } was selected. Crop rotation rice-wheat was used. Sesbania crop was sown before the transplanting of every rice crop and it was incorporated after 45 days of sowing. Analysis of data indicated that different tillage implements with urea enhanced the decomposition of sesbania and significantly improved soil pH_s,EC_e, SAR, HC, BD and rice-wheat yield. Maximum paddy and grain yield was observed in treatment where disc harrow was used with fertilizer level of urea @ 40 kg ha^{-1}. So incorporation of sesbania with disc harrow along urea supply @ 40 kg ha^{-1} is therefore seen as a potential agro ecological innovation that promote a better utilization of sesbania in salt affected.

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Introduction

Soil degradation due to salinization is a major threat to global agriculture (Devkota *et al.,* 2015) which have negative impacts oncrop growth and soil properties (Okur, 2002). Salt prone soils generally provide unfavorable condition for plant growthas they are typically coupled withexcessive soluble salts and insufficient organic matter(Asmalodhi *et al.,* 2009).Improvement in physical and chemical properties of such problematic soils could be achieved by different methods, governed by available resources and local conditions (Elsharawy *et al.*, 2008).Deleterious consequences of salinization could be reduced by addition of organic materials in salt affected soil (Pang *et al.,* 2010).Organic amendments improve health due to long-lasting ameliorative effects on soil-quality characteristics (Hueso-González *et al.,* 2014;Baldi and Toselli, 2014). It not only precludes the salt prone degradation of soil but also preserves its productivity and fertility status (Rekhi *et al.,* 2000).Due to arid to semi-arid climate, Pakistani·s soils are generally poor in organic matter because of remineralization rates of organic matterrather than its addition in these soils. In current scenario, green manuring with leguminous crops can serve as a cheaper source of nutrient for establishment of plants on salt affected soils. At the same time green manuring maintain the status of soil N (Mohammad *et al.*, 2008), improves organic C contents of soil (Bakht *et al.*, 2009).

The sesbania, a high N_2 fixing legumeis annuals, short-lived plant which have ability to tolerate salt stress (Evans and Rotar, 1987) and can fix upto 270 kg of nitrogen ha^{-1} in 52 days (Yang *et al.*, 1998). On decomposition, it not only enhanced the fertility status of soil but also improves aeration, water holding capacity, colloidal complex and consequently the ability of soil to retain nutrients.Therefore Inclusion of this short-lived plant in wheat-rice rotation helps in maintaining soil fertility and increased crop productivity (Mishra *et al.*, 2006;Shah *et al.,* 2011). Green manuring of sesbania significantly increase the rice and wheat crop yield with 50 to 60 % N saving and improve the soil health by up-lifting physico-chemical properties (Mann *et al.*, 2000). Integration of fertilizers with green manuring of guar and sesbania had positive effects on rice and wheat crop yield (Ibrahim *et al.*, 2000). The involvement of sesbania and mung bean has shown positive impacts in rice-wheat cropping sequence (Mann, 2000). Furthermore, it has been widely reported that the application of organic material not only improve nutrients but also has positive impacts on other soil chare cteristics such as better porosity, aeration, temperature, water holding capacity, microbial activities and many others (Prakash *et al.*, 2007).

Soil compaction is a well-recognized problem in global agriculture (Hamza and Anderson 2005) and this situation is exacerbated by salt stressed degraded soils which posea prompt threat to crop growth and economic yields, in addition to a long term hazard to future crop yields. Due to excess of Na^+ in salt affected soils hydraulic conductivity is limited due to dispersion, translocation and deposition of clay particles in conducting pores (Mari *et al.*, 2011).The only proper way to improve soil physical properties and favourable crop growth conditions is management by tillage practices (Mosaddeghi *et al.* 2009).Tilling is soil manipulation for good seedbed preparation and root penetration and growth. Tillage not only considerably decreased penetration resistance and soil bulk density, but also improved soil water content and root length (Ji B., 2013).Hence it is indispensable to select a tillage system that sustains and improve the soil properties required for successful crop growth (Jabro *et al.*, 2009).

Keeping the above facts in view a study was planned to develop the best technique for decomposition of sesbania with urea fertilizer and tillage implements in saline sodic soil.

Materials and methods

A series of experiments was conducted during 2011 to 2014adopting rice-wheat croppingi.e starting in mid-July 2011 (rice) and ending in April 2014 (wheat) at research farm of Soil Salinity Research Institute, Pindi Bhattian having coordinates, (altitude 184 m, latitude 31.8950° N and longitude 73.2706° E). A salt affected field {EC_e = 6.50 (d Sm^{-1}), pH_s = 8.90, SAR = 45.70 (m mol $L^{-1})^{1/2}$ and soil gypsum requirement (SGR) = 11.04 t ha^{-1} for 0-15 cm} was selected and prepared by using three tillage implements cultivator, disk harrow and rotavator according to the treatments, whereas two fertilizer levels i-e urea 40 kg ha^{-1} and urea 0 kg ha^{-1} were used to enhance the decomposition of sesbania. Experiment was designed in randomized complete block design having split plot arrangement with three repeats having subplot size 8m x 6m.Tillage implements were kept in main plots and fertilizer levels in sub-plots. The average weather conditions were: 11.8 ± 4.4°C minimum temperature, 42.6 ± 2.5°C maximum temperature, 36.2 ± 3.5% minimum relative humidity, 72.3 ± 4.8% maximum relative humidity, maximum sunshine hours, 14 h and 10 minute and minimum sunshine hours7 h and 35 minute.

Sesbania crop @ 50 kg ha^{-1} seed was sown before the transplanting of every rice crop and incorporated after 45 days of sowing. Recommended dose of fertilizers110-90-60 NPK kg ha^{-1} for rice (Shaheen Basmati) and 120-110-70 NPK kg ha^{-1} for wheat (Inqlab-91) was applied as urea, single super phosphate (SSP) and sulphate of potash (SOP).

Observations Recorded

Composite soil samples were collected before sowing and after the harvest of each crop in each season and were analyzed for soil parameters like bulk density, hydraulic conductivity, pH_s, EC_e and SAR by adopting the protocol as reported by the US Salinity Lab. Staff (1954). Paddy/grain yield was recorded at time of harvesting of each crop.

Statistical Analysis

The data generated was subjected to analysis of variance (ANOVA) technique and the least significance difference (LSD) test was used to separate the differences among treatment means (Steel *et al.*, 1997) using STATISTIX 8.1 package software.

Results

Rice

In rice 2011, paddy yield (2.18 t. ha^{-1}) was significantly higher with application of urea @ 40 kg ha^{-1} and with respect to tillage implements maximum paddy yield (2.07 t. ha^{-1}) was recorded when disc harrow was used for incorporation of sesbania and soil preparation (Table 1).

Table 1. Effect of urea and tillage implements on paddy yield (t ha^{-1}) 2011.

Treatments	Urea 40 (kg ha^{-1})	Urea 0 (kg ha^{-1})	Mean
T_1: Cultivator + Planking	2.08 c	1.59 f	1.84 C
T_2: Disk harrow	2.32 a	1.82 d	2.07 A
T_3: Rotavator	2.15 b	1.63 e	1.89 B
Mean	2.18 A	1.68 B	
LSD for treatment=0.0222	LSD for fertilizer=0.0269	LSD for Interaction=0.0313	

Any two means sharing the same letters are statistically similar at *P =0.05*.

Data regarding interactive effect of urea and tillage implements showed that urea application @ 40 kg ha^{-1} with disk harrow yielded significantly higher grain yield of (2.32 t. ha^{-1}).Same trend was observed in successive years, maximum paddy yield (2.41 t. ha^{-1}) and (2.74 t. ha^{-1}) was obtained with application of urea @ 40 kg ha^{-1} during 2012 and 2013 respectively (Table 2 and 3).Further it was inferred that tillage implements have their own importance in salt affected soil and disc harrow enhanced the decomposition process and resultantly paddy yield was also improved as compared to other tillage implements. Paddy yield of rice 2012 was (2.46 t. ha^{-1}) and rice 2013 was (3.05 t. ha^{-1}) with disc harrow.

Minimum paddy yield was obtained by using the cultivator + planking, in all three consecutive seasons. Tillage system and urea interaction was also found significant it was observed that paddy yield was 2.70 t. ha^{-1} in (2012) and 3.21 t. ha^{-1} in (2013) using disc harrow and urea fertilizer @ 40 kg ha^{-1}.

Wheat

A perusal of data regarding the wheat grain yield it could be observed that urea levels, tillage implements and their interactive effect significantly (P ≤ 0.05) increased grain yield. For wheat 2011-12, grain yield (2.2t. ha^{-1}) was significantly higher with application of urea @ 40 kg ha^{-1} and in respect to tillage systems maximum grain yield (2.17 t. ha^{-1}) was documented with disc harrow(Table 4).Interaction of urea levels and tillage implements showed that greater grain yield (2.40 t. ha^{-1}) was produced by urea @ 40 kg ha^{-1}with disc harrow.

Table 2. Effect of urea and tillage implements on paddy yield (t ha^{-1}) 2012.

Treatments	Urea 40 (kg ha^{-1})	Urea 0 (kg ha^{-1})	Mean
T_1: Cultivator + Planking	2.10 d	1.82 e	1.96 C
T_2: Disk harrow	2.70 a	2.22 c	2.46 A
T_3: Rotavator	2.45 b	2.07 d	2.26 B
Mean	2.41 A	2.04 B	
LSD for treatment=0.0904:	LSD for fertilizer=0.0493:	LSD for Interaction=0.0854	

Any two means sharing the same letters are statistically similar at $P = 0.05$.

In wheat 2012-13 and 2013-14, maximum grain yield (2.36 t. ha^{-1}) and (2.79 t. ha^{-1}) was obtained with application of urea @ 40 kg ha^{-1}which is similar to 2011-12 results(Table 5 and 6). Among three tillage system it was observed that disc harrow yielded maximum grain yield (2.43 t. ha^{-1}) and(2.91 t. ha^{-1}) in 2012-13 and 2013-14 respectively.Interactive effect of urea levels and tillage system showed that maximum grain yield was recorded using tillage implement disc harrow with urea fertilizer @ 40 kg ha^{-1} in first, second and third wheat crop. Minimum grain yield was observed with cultivator + planking and urea @ 0 kg ha^{-1} for all three consecutive seasons.

Table 3. Effect of urea and tillage implements on paddy yield (t. ha^{-1}) 2013.

Treatments	Urea 40 (kg ha^{-1})	Urea 0 (kg ha^{-1})	Mean
T_1: Cultivator + Planking	2.22 c	1.98 d	2.10 C
T_2: Disk harrow	3.21 a	2.89 b	3.05 A
T_3: Rotavator	2.78 b	2.67 b	2.72 B
Mean	2.74 A	2.51 B	
LSD for treatment =0.2016	LSD for fertilizer = 0.1845	LSD for Interaction=0.2216	

Any two means sharing the same letters are statistically similar at $P = 0.05$.

Soil properties

Results revealed that irrespective of the tillage implements and urea levels used, soil chemical and physical properties were markedly improved by all the treatments after three years of experimentation (Table 7). Results of soil analysis showed that pH_s value reduced to 1.57%, 2.25 % and 2.02 % with respect to their initial value by cultivator, disc harrow and rotavator respectively using urea @ 0 kg ha^{-1}fertilizer. While using urea fertilizer @ 40 kg ha-

[1]pH_svalue reduced to 2.36 %, 2.70 % and 2.58 % with tillage implements cultivator, disc harrow and rotavator respectively.

There was a significant reduction in electrical conductivity values at the end of experiment. EC_e reduced to 20 %, 31 % and 26 % using cultivator, disc harrow and rotavator with urea @ 0 kg ha^{-1}. While with application of urea @ 40 kg ha^{-1} maximum reduction was observed indisc harrow (36 %) followed by rotavator (34 %) and minimum reduction was noted with cultivator(21 %) with respect to their initial values.

Table 4. Effect of urea and tillage implements on wheat grain yield (t. ha^{-1}) 2011-12.

Treatments	Urea 40 (kg ha^{-1})	Urea 0 (kg ha^{-1})	Mean
T_1: Cultivator + Planking	1.96 c	1.71 e	1.83 C
T_2: Disk harrow	2.40 a	1.94 c	2.17 A
T_3: Rotavator	2.24 b	1.87 d	2.05 B
Mean	2.20 A	1.84 B	
LSD for treatment=0.0190; LSD for fertilizer=0.0126; LSD for Interaction=0.0268			

Any two means sharing the same letters are statistically similar at $P = 0.05$.

Similarly SAR values reduced to 32 % by cultivator, 46% by disc harrow and 42 % by rotavator without using urea fertilizer. While using urea fertilizer @ 40 kg ha^{-1} SAR values reduced to 38 %, 48 % and 45 % with tillage implements cultivator, disc harrow and rotavator respectively.

Sesbania green manure decomposition also improved physical properties of soil (Table 8). Maximum increased in hydraulic conductivity of soil was observed with urea application @ 40 kg ha^{-1}. Disc harrow increased the hydraulic conductivity 81 % with respect to their initial value while increased was only 74 % with rotavator and 40 % with cultivator. Vice versa trend was observed in case of bulk density, disc harrow, rotavator and cultivator reduced bulk density valu up to 16 %, 14 % and 8 %, with urea fertilizer @ 40 kg ha^{-1}.

Table 5. Effect of urea and tillage implements on wheat grain yield (t. ha^{-1}) 2012-13.

Treatments	Urea 40 (kg ha^{-1})	Urea 0 (kg ha^{-1})	Mean
T_1: Cultivator + Planking	2.01 d	1.78 e	1.89 C
T_2: Disk harrow	2.66 a	2.22 c	2.43 A
T_3: Rotavator	2.42 b	2.00 d	2.21 B
Mean	2.36 A	2.00 B	
LSD for treatment=0.0574	LSD for fertilizer=0.0216	LSD for Interaction=0.0916	

Any two means sharing the same letters are statistically similar at $P = 0.05$.

Discussion

Selection of an organic source is very important as incorporation of low quality organic source to soil may decreased crop yield as well as nutrients availability (Hemwong *et al.*, 2008; Gentile *et al.*, 2009). Mineralization of nutrients from an organic source is functionally associated with different biotic and abiotic factors (Berg and Mc Claugherty, 2008) and is strongly dependent on its chemical composition, higher quality plant material with narrow C:N ratio will be mineralized fast while low-quality plant material with high C:N ratio will have a lower mineralization rate and may immobilized by soil microbes which reduces plant available nitrogen contents (Gentile *et al.* 2009). Crops with low C:N ratio decomposed fast and easily and significantly increased the organic carbon, nitrogen and phosphorus contents in soil under rice-wheat cropping system (Shindo and Nishio, 2005). Sesbaniabeing leguminous crop also decomposed easily, however in salt affected soils due to poor organic matter and nitrogen content (Ashraf and Rehman, 1999) nitrogen status of the sesoils may not be comparable to normal agricultural soils (Asmalodhi *et al.*, 2009).

Table 6. Effect of urea and tillage implements on wheat grain yield (t. ha^{-1}) 2013-14.

Treatments	Urea 40 (kg ha^{-1})	Urea 0 (kg ha^{-1})	Mean
T_1: Cultivator + Planking	2.23 c	1.78 d	2.00 B
T_2: Disk harrow	3.19 a	2.64 b	2.91 A
T_3: Rotavator	2.95 a	2.42 bc	2.67 A
Mean	2.79 A	2.28 B	
LSD for treatment =0.2499	LSD for fertilizer = 0.0994	LSD for Interaction=0.1723	

Any two means sharing the same letters are statistically similar at $P = 0.05$.

Furthermore, excessive solube salts inhibits mineralization of organic materials and soil enzyme activities which are essential for the decomposition of organic matter and release of nutrients required to sustain productivity (Nourbakhsh *et al.*, 2006).Hence under salinized environment, the role of N becomes vital and externally applied any inorganic nitrogen source will improve residues quality and alter its chemistry that may changes microbial community as residues are decomposed (Stemmer *et al.* 2007; Gentile *et al.* 2009) and consequently N availability status also improved (Walpola and Arunakumara 2010).So Priming of organic material with nitrogen source is necessary to accelerate mineralization process and to avoid imboliztion (Partey *et al.*, 2014). In our study more paddy/grain yield of wheat and rice in treatment where urea @ 40 kg/ha was applied to decompose sesbaian could be attributed to improve nitrogen composition in salt affected soil and low C/N ratios and supply sufficient N for decomposing microorganisms, thus eliminating any period of net N immobilization (Gentile *et al.* 2009; Qiu *et al.* 2016).

Table 7. Soil Analyses at the end of study.

Treatments	pH		EC_e(dS m^{-1})		SAR(mmol L^{-1})$^{1/2}$	
	Urea 40 (kg ha^{-1})	Urea 0 (kg ha^{-1})	Urea 40 (kg ha^{-1})	Urea 0 (kg ha^{-1})	Urea 40 (kg ha^{-1})	Urea 0 (kg ha^{-1})
Cultivator+ Planking	8.69	8.76	5.11	5.21	28.46	31.19
Disc Harrow	8.66	8.70	4.16	4.48	23.58	24.68
Rotavator	8.67	8.72	4.27	4.83	24.97	26.54

Inclusion of green manures crop in rice wheat rotation helps to improves organic C, mineralizable N contents,(Abbasi *et al.*, 2009) Zn and Cu Mishra *et al.* (2006) microbial activities(Shah *et al.*, 2010) and increases uptake of P, K, Zn, Fe, Mn, Cu by rice plants (Srirama chandrasekharan, 2001) Mann *et al.* (2000) stated that yield of rice crop increased considerably by green manuring of sesbania. They also reported that continuous use of green manuring of sesbania rostrate for three years not only improved the soil health in terms of its physical and chemical properties but also had beneficial residual effect on the succeeding wheat crop. Similar findings were also reported by Ibrahim *et al.* (2000) that integration of fertilizers with green manuring of guar and sesbania had positive effects on rice and wheat crop yield. Beneficial effects of green manuring in wheat and rice crop has been reported by Boparai *et al.* (1992) which reinforced our findings. Green manuring of sesbania aculeate help to uplift soil characteristics of wet-land rice as its incorporation significantly increased root growth and grain yield of wheat grown after rice (Shah *et al.*, 2011).More crop yield with tillage by disc harrow may be justified as decomposition of organic source incorporated into soil is enhanced as compared to crop residue placement on soil surface (Burgess *et al.* 2002) furthermore proper placement of crop residue in soil also affect the balance between gross nitrogen immobilization and gross nitrogen mineralization process (Burgess *et al.* 2002). Reductionin tillage practices may results accumulation of organic matters in upper layers of soil (Pekrun *et al.* 2003), may disturb microbial activates as well as microbial biomass and distribution and amounts of mineralize able nitrogen (Kandeler *et al.*, 1999). Deep ploughing altered soil climate in term of temperature and moisture and all these modifications accelerated the decomposition of sesbania in turn enhancing the soil nitrogen supply to corps.

Table 8. Soil Analyses at the end of study.

Treatments	HC (cm hr^{-1})		BD (Mg m^{-3})	
	Urea 40 (kg ha^{-1})	Urea 0 (kg ha^{-1})	Urea 40 (kg ha^{-1})	Urea 0 (kg ha^{-1})
Cultivator + Planking	0.66	0.62	1.36	1.39
Disc Harrow	0.85	0.80	1.25	1.29
Rotavator	0.82	0.77	1.28	1.33

Soil qualities

Sesbania green manuring is a common practice on salt-affectedsoils in terms of their rehabilitation and an increase in nutrient availability status (Qadir *et al.*, 2002;Baig*et al.* 2005a,b).In ours study decreased in salinity indicators (pH_s, $EC_e$and SAR) were due to phytoremediation of salt affected soils (Ahmed, 1991) which occur during the release of root exudates and organic carbon(Treeby*et al.*, 1989)changes in soil pH (Liu *et al.*, 1989) due to acidic nature(cytoplasmic pH is about 4.01) of sesbania(Uppal, 1955) which decrease the soil pH value from (8.90) to (8.66) in treatment with disc harrow plus urea @ 40 kg ha^{-1}at the end of study. Additionally when sesbania buried as green manure CO_2 evolved during decomposition and formed carbonic acid, which solubilizes lime and thus helps in the reclamation process (Quadir, *et al.*, 2001).Our results are reinforced by several researchers who reported sesbania helped in reclamation of sodic soil by lowering the adverse effects of Na^+(Baig *et al.*, 2005),help to balance nutrient supply and act as a buffer against salinity/sodicity by lowering pH (Baig and Zia, 2006) also improve the soil structure, infiltration and hydraulic conductivity (Turgut *et al.*, 2005) better aeration, temperature, porosity, microbial activities, water holding capacity and many others (Khan *et al.*, 2010).Furthermore, crop also benefited by better soil physical properties as improved by different tillage systems (Mosaddeghi *et al.* 2009).The lowest values of bullk density and hydraulic conductivity at end of study in treatment with disc harrow and urea @ 40 kg ha^{-1}could be due to their ability in breaking, tearing and inverting the soil and well chopping and mixing of sesbania in soil consequently the most favorable soil conditions (i.e. low soil penetration resistance and bulk density, more soil moisture content and porosity). Similar findings were mentioned by (Ji, 2013; Amin *et al.*, 2014; Nayel *et al.*, 2016).

Abbreviations used

EC_e(electrical conductivity of soil extract); pH_s (pH of soil saturated past); SAR (sodium absorption ratio);

SGR (soil gypsum requirement); HC (hydraulic conductivity); BD (bulk density)

Conclusion

Incorporation of sesbania with disc harrow alongurea supply @ 40 kg/ha is therefore seen as a potential agro ecological innovation that promote a better utilization of sesbania in salt affected which add organic matter and stimulate mineralization of essential nutrients to plant, thus enhancing soil fertility and productivity through improved soil physical, chemical and biological properties.

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