Journal of Experimental Biology and Agricultural Sciences, October - 2019; Volume – 7(5) page *** – ***

Journal of Experimental Biology and Agricultural Sciences

http://www.jebas.org

ISSN No. 2320 – 8694

SUBSURFACE DRAINAGE SYSTEM AND AMENDMENTS ON CUMBU NAPIER HYBRID GRASS IN WATERLOGGED SALINE ALKALI SOIL

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Received –April 02, 2019; Revision – June 29, 2019; Accepted – August 20, 2019
Available Online – October **, 2019

DOI: http://dx.doi.org/10.18006/2019.7(5).***.***

KEYWORDS

Waterlogging

Subsurface drainage system

Organic amendments

Saline-alkali soil

CN hybrid grass

Green fodder

Crude protein

ABSTRACT

The area under waterlogged saline-alkali soil increasing over years in treated industrial effluent irrigated areas and in canal irrigated areas. The agricultural drainage system installed in the field to remove the excess water and salt to ensure a good crop, prevention of in-and off-season waterlogging, prevention of salinization of the soil by irrigation or by the capillary rise of groundwater. A field experiment was conducted to assess the effect of the subsurface drainage system and organic amendments (Farm Yard Manure, pressmud, vermicompost, MLSS compost, and biochar) on growth, yield and quality characteristics of Cumbu Napier hybrid (CN hybrid) in waterlogged saline-alkali soil with different treatment combinations. The experiment showed that the application of FYM @ 12.5 t ha^{-1} along with gypsum requirement and the entire dose of fertilizer in the drained field increased the plant height, green fodder yield of CN hybrid by 30.0 percent as compared to undrained control field.

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Peer review under responsibility of Journal of Experimental Biology and Agricultural Sciences.

Production and Hosting by Horizon Publisher India [HPI]
(http://www.horizonpublisherindia.in/).

1 Introduction

The availability of fresh water for the agricultural sector in the future will probably be reduced in the world, particularly in Asian countries due to population pressure, improved living standards and inter-sectoral competition for water. The estimate for India showed that this reduction would be 10-12% by 2025 and at the same time it is expected that the total water demand will increase by 22% by 2025 and by 32% by 2050 (Amarasinghe et al., 2007). At the same time, global water demand expected to increase by 55% by 2050, largely due to the increase in domestic, industrial and energy demand (Leflaive, 2012). The requirement of water to meet the needs of domestic, industrial and other agriculture activities indicates the need to regenerate wastewater, which is an economical and attractive alternative to dry areas to irrigate crops to maintain productivity (Sharma et al., 2014). Various researchers evaluated the quality of the paper mill effluent and suggested that paper mill effluent contains not only nutrients for plants but is also loaded with a certain amount of polyelectrolyte used during the papermaking process (Tripathi et al., 2013; Yadav &Yadav, 2014; Sharma & Ramotra, 2014). With an average of 143 m^3 of water used per ton of paper production, this water reappears as wastewater and can be used for crop production after appropriate treatment. Most (~ 80%) of wastewater is discharged into water bodies (rivers, lakes and sea) with little or no treatment and a poor portion (14% in Indonesia, 10% in the Philippines, 9% in India and the 4% in Vietnam), of them treated primarily or completely (ADB, 2016) and discharged in to environmental media. Continuous irrigation with treated effluents and poor management practices over a period reduced the productivity of agricultural crops due to water stagnation and salinization(Udayasoorian et al, 1999). Soil quality deterioration and productivity decline forcing the farmers to go for saline tolerant crops and farmers are now switching to coconut-based intercropping with Cumbu Napier (CN) hybrids and livestock activities in areas irrigated by treated paper effluents (Udayasoorian et al, 1999; Balusamy et al., 2013).

In the semi-arid area, salts generally accumulate in the upper soil profiles, especially when they are associated with insufficient leaching and lead to the development of saline and alkaline conditions, water stagnation and reduction in yield (Blaylock, 1994; Shrivastava &Kumar, 2015). The high salinity can interfere with the growth of vegetation and, consequently, less water absorbed by plants causes a delay in growth and reduces the yield of crops.Worldwide more than 30-million-hectares of land affected by salinity and waterlogging problems (Bakker et al., 2010). The seasonal waterlogging reduced the thickness and stability of B horizon due to increase in content of soil exchangeable sodium, which demands measures such as drainage (surface & subsurface) and some eco-friendly practices to restore the soil health in waterlogged soils (Choudhury et al., 2016). Use of tolerant varieties, good quality water, appropriate soil amendments and proper drainage system will improve the soil and crop environment in saline alkali soil (Grattan & Oster, 2003).

Subsurface drainage systems often used on irrigated and waterlogged soils in arid and semi-arid regions to reduce or prevent water waterlogging and soil salinity; offers many advantages that will be needed to address these challenges in humid and arid areas (Ayars & Evans, 2015). Drainage system not only solve the problem of waterlogging and salinity, it also improves the productive capacity of land by preventing loss of sediments and phosphorus thereby improves the growth and yield of crops (Ambast et al., 2007; Prasad et al., 2007; Chahar & Vadodaria, 2008: Ritzema, 2009; Ritzema & Schultz, 2011). Early studies showed that there were moderate increases in the yield of many crops after improved drainage, but greater increases in productivity (> 100% increase in yield) could be achieved when improving drainage together with good management of fertility (Schwab et al., 1966). The subsurface drainage system has increased the yield of many crops such as rice (10-69%), berseem (48%), maize (75%), wheat (130-136%), sugarcane (54%), cotton (64%), and this increase can be attributed to the decrease in soil salinity, to the improvement of air and water conditions in the root zone of crops (Abdel-Dayem & Ritzema, 1990; Ritzema et al., 2008; Ritzema, 2009). Adoption of the subsurface drainage system is probably one of the best ways to increase resource use efficiency in order to increase crop production and sustain natural resources like soil and water in severely waterlogged saline soils. There is a great demand for research and development efforts to recover all the soils affected by waterlogging and salts, by providing drainage and bringing them back to productive land. This study also aims at reverting back the waterlogged saline alkali soil into productive land by means of subsurface drainage system and amendments, its effects on growth, yield and quality characteristics of Cumbu Napier grass in treated paper mill effluent irrigated areas.

2 Materials and Methods

A field experiment was conducted to assess the impact of the drainage system and various amendments on growth, yield, crude protein and crude fiber content of Cumbu Napier hybrid grass in waterlogged saline-alkali soil of Pandipalayam Village, Karur District of Tamil Nadu during 2014-15. The subsurface drainage system installed in 15 m lateral spacing's using perforated corrugated pipe of 80 mm diameter. The field ploughed thoroughly, beds and channels made to plant the Cumbu Napier slips. The Cumbu Napier variety CO (CN) 4 slips were planted by adopting spacing of 50 x 50 cm in ridges and furrows on September 2014. The first harvest was made 90 days after sowing and the subsequent harvest was carried out in a 45-day interval. The effluent from the treated paper mill was used as an irrigation source throughout the experimental period. After each cut, 75 kg of N were applied per ha.

2.1 Treatment Details

Main Plot

M_1 : Subsurface drainage system field;
M_2 : undrained field

Sub plot

T_1 : Control;
T_2 : 100 % GR;
T_3 : 100 % GR + FYM @ 12.5 t ha^{-1};
T_4 : 100 % GR + MLSS compost @ 5.0 t ha^{-1};
T_5 : 100 % GR + Vermicompost @ 5.0 t ha^{-1};
T_6 : 100 % GR + Pressmud @ 5.0 t ha^{-1};
T_7 : 100 % GR + Biochar @ 5.0 t ha^{-1}

Common application: Recommended dose of NPK: 150:50:50 kg ha^{-1}; GR - Gypsum Requirement; FYM - Farm Yard Manure; MLSS compost – Mixed liquid suspended solids compost

2.2 Data collection

The pH, EC of organic amendments measured with amendments water suspension of 1:10 ratio using pH and conductivity meter, organic carbon by chromic acid wet digestion method, total nitrogen by semiautomatic Kjeldal distillation method using diacid extract. Total phosphorus, total potassium, total Ca & Mg extracted by triacid extract. The total phosphorus was estimated by Vanadomolybdate yellow colour development, potassium by flame photometer and total Ca and Mg by versenate method.

The biometric observations were recorded by randomly selecting five hills, of which two tillers from each hill were selected for observation and marked within the net plot area. The selected parameters such as plant height, green fodder yield and crude protein content were made in the harvest stage and the average values were calculated. Growth attributes such as plant height, green forage yield were recorded according to standard procedures and average values obtained were expressed based on the SI unit system.

The height of the plant was measured from the ground level to the plant tip at 90, 135 and 180 days after planting and was expressed in centimeters (cm). The harvesting was done above ground level in each plot and the total green biomass was weighed and expressed in t ha^{-1}. The total crude protein content was derived by multiplying the total nitrogen by a factor of 6.25 and expressed as a percentage (Humphries, 1956). The crude fiber in the forage was estimated by subsequently boiling a known weight of plant sample (2 g) with diluted sulfuric acid (1.25%) and sodium hydroxide (2.5%), thus imitating the gastric and intestinal action during the digestion process. The material left undissolved was, considered as a raw fiber and expressed as a percentage (Goering &Vansoest, 1970). The experimental results were statistically analyzed as suggested by Panse & Sukhatme (1985) to find out the influence of various treatments (drainage system and amendments) on the response of the plant. The critical difference was worked out with a probability of 5% (0.05).

3 Results

3.1 Characteristics of amendments

The pH of organic amendments was neutral in reaction, with the exception of biochar (Table 1). Among the organic amendments, the lowest EC of 0.98 dS m^{-1} was recorded in biochar, followed by vermicompost (1.20 dS m^{-1}), FYM (1.26 dS m^{-1}), pressmud (1.67 dS m^{-1}) and MLSS compost (1.98 dS m^{-1}). The highest nitrogen content of 1.62 percent recorded in the pressmud followed by vermicompost (1.52 percent), FYM (1.25 percent) and MLSS compost (1.16 percent).

Table 1 Characteristics of organic amendments

Parameters	Pressmud	FYM	MLSS compost	Vermicompost	Biochar
pH	7.16	7.56	7.68	7.46	8.59
EC (dS m^{-1})	1.67	1.26	1.98	1.20	0.98
Organic carbon (%)	29.60	26.30	21.5	24.6	7.60
Total nitrogen (%)	1.62	1.25	1.16	1.52	0.39
Total phosphorous (%)	1.46	0.55	0.59	1.32	0.18
Total potassium (%)	0.70	0.86	1.22	0.98	1.40
Total calcium (%)	1.50	0.90	1.71	1.40	1.12
Total magnesium (%)	0.44	0.32	0.85	0.69	0.98
C : N ratio	18.27	21.04	18.53	16.18	19.48

(MLSS- Mixed Liquor Suspended Solids, FYM- Farm Yard Manure)

Similarly, among the various tested amendments, the highest phosphorus content of 1.46 percent recorded in pressmud followed by vermicompost (1.32 percent). Further, highest potassium was observed in biochar (1.40 percent) followed by MLSS compost (1.22 percent) and highest organic carbon content of 29.60 percent observed in the pressmud followed by FYM (26.30 percent). In general, all the amendments had an appreciable amount of secondary nutrients such as calcium and magnesium.

3.2 Effect of the drainage system and amendments on plant height

The drainage system and the application of different amendments levels have considerably improved the height of the CN hybrid grass (Figure 1). The height of the plant ranged from 186 to 270 cm, from 136 to 218 cm and from 125 to 204 cm, in the first, second and third cuttings respectively. Significantly higher plant height was recorded in the drained field rather than the undrained field. Among the treatments, application of FYM 12.5 t ha^{-1}+ 100% GR + RDF (T_2) recorded the maximum plant height of 270, 218 and 204 cm, during the first, second and third cuts in the drained field (M_1) respectively followed by application of Vermicompost @ 5t ha^{-1}+ 100% GR + RDF (T_5) and (Pressmud @ 5t ha^{-1}+ 100% GR + RDF (T_6). The minimum plant height of 186, 136 and 125 cm was recorded in control (T_1), in the first, second and third cuts respectively in undrained field conditions. The interaction between the drainage system and the amendments was not significant in the first cut.

3.3 Effect of the drainage system and amendments on green fodder yield

The subsurface drainage system and amendments significantly increased the yield of green fodder and a relatively higher yield was recorded in the drained field rather than the undrained field. The yield of green fodder ranged from 40.3 to 57.6, from 35.5 to 52.4 and from 34.7 to 50.8 t ha^{-1}in the first, second and third cuts, respectively (Figure 2). Among the amendments, the application of FYM @ 12.5 t ha^{-1}+ 100% GR + RDF (T_3) recorded the highest yield of 57.6, 52.4 and 50.8 t ha^{-1}, in first, second and third cut respectively under the subsurface drainage system. The lowest green forage yield of 40.3, 35.5 and 34.7 t ha^{-1} recorded in Control (T_1), in the first, second and third cut, respectively in field conditions without drainage. It was found that the interaction between the drainage system and the amendments was not significant at all stages.

3.4 Crude protein

In general, there was an increasing trend of crude protein content recorded from the first to third cut and significantly higher crude protein content was recorded in the drained field rather than the non-drained field. The range was reported between 7.98 and 9.99, 8.07-10.1 and 8.11- 10.16%, in the first, second and third cuts respectively (Figure 3). Like others parameters, application of FYM @ 12.5 t ha^{-1}+ 100% GR + RDF (T_3) recorded a significantly higher crude protein content of 9.99% in the first cut followed by application of vermicompost @ 5.0 t ha^{-1}+ 100% GR + RDF (T_5) and pressmud @ 5t ha^{-1}+ 100% GR + RDF (T_6), which were at par with each other in the drained field conditions. The similar trend was noted for the second and third cuts. The raw protein content of 7.98 percent was recorded in Treatment 1 under undrained field conditions in the first cut, which was at par with Treatment 2. A similar trend was also recorded during the second and third cut. It was found that the interaction between the drainage system and the amendments was not significant in the three cutting phases.

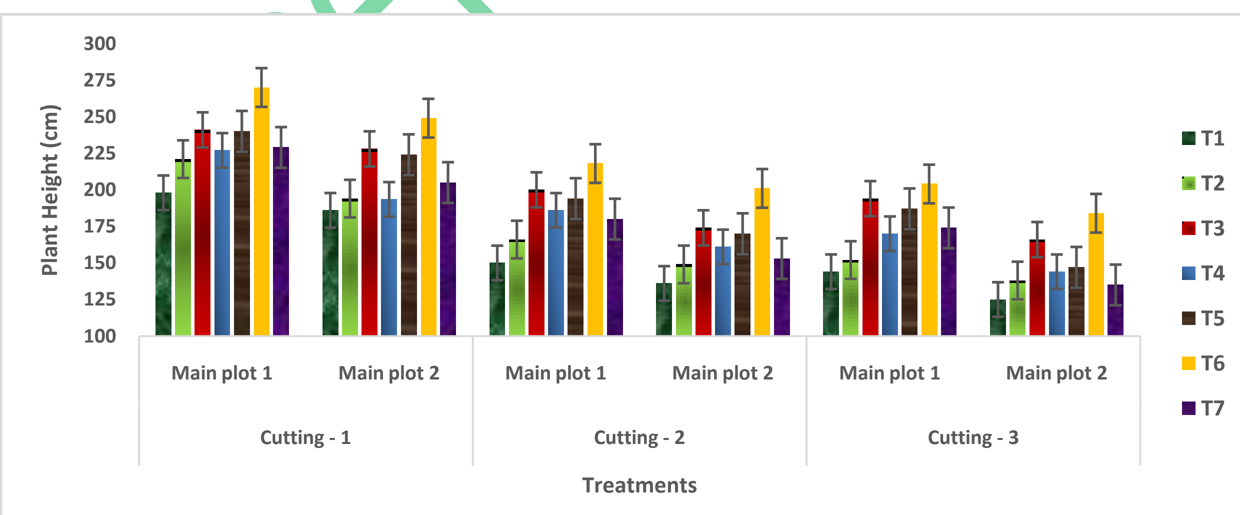

Figure 1 Effect of subsurface drainage system and amendments on plant height

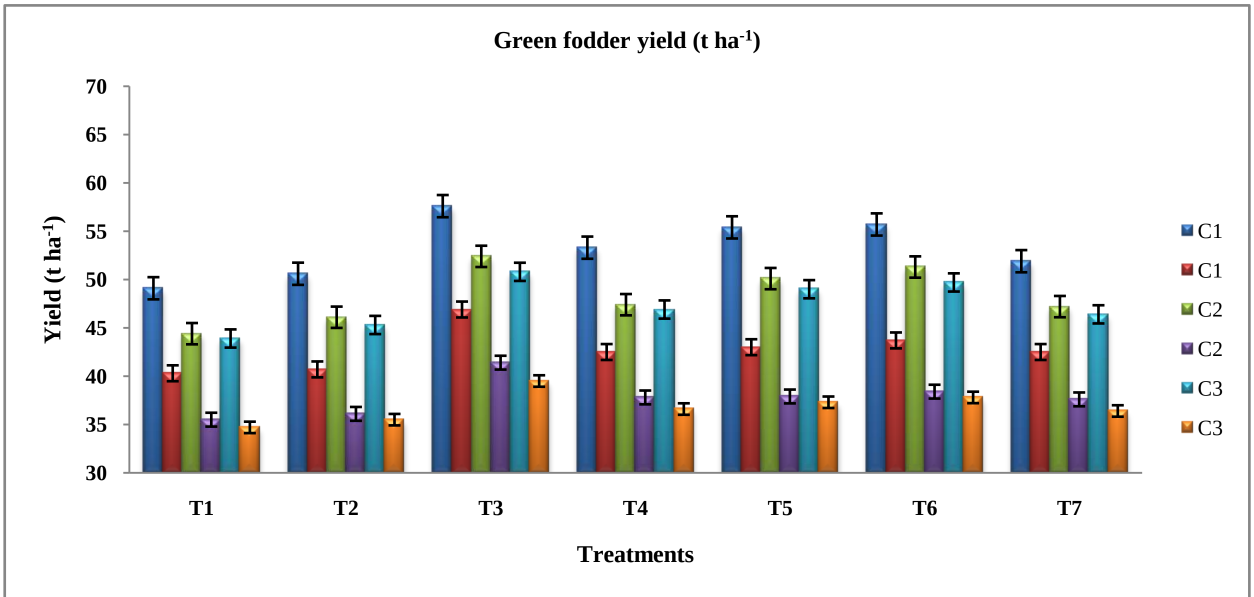

Figure 2 Effect of subsurface drainage system and amendments on green fodder yield

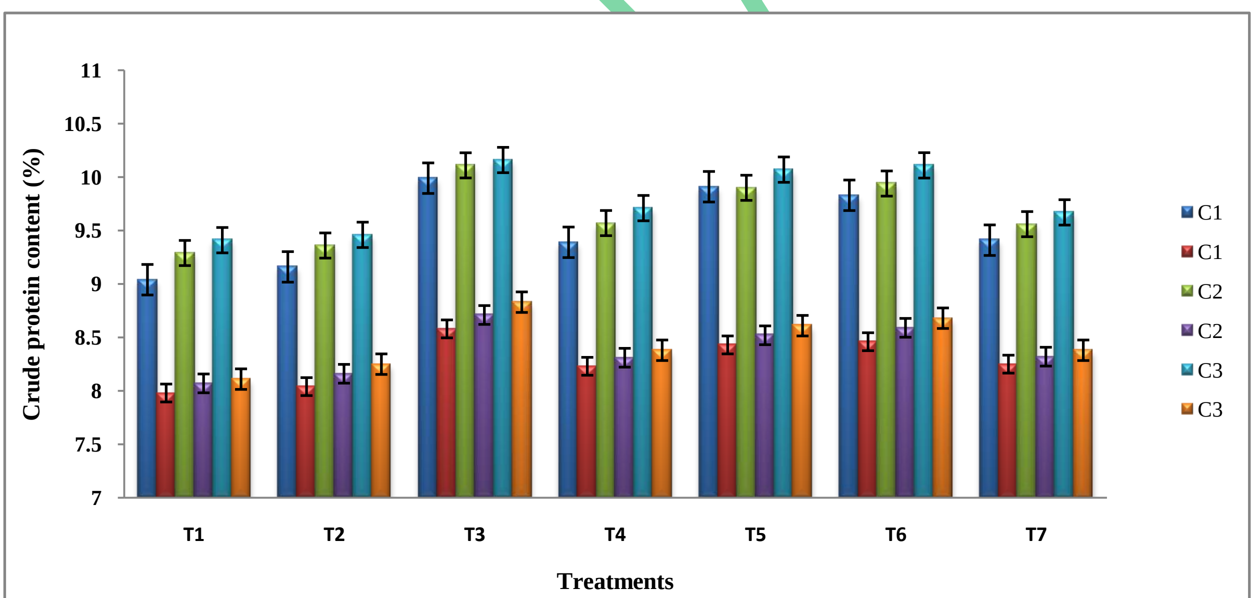

Figure 3 Effect of subsurface drainage system and amendments on crude protein content

3.5 Crude fiber content

The application of the amendments has significantly reduced crude fiber content in different treatments. The values ranged from 26.0 to 27.5, from 25.8 to 27.4 and from 25.5 to 27.2 percent, during the first, second and third cuts respectively (Table 2). Among the amendments, the lowest crude fiber content of 26.0, 25.8 and 25.5 percent was recorded in Treatment 3 (100% GR + RDF +12.5 t ha^{-1} FYM), during the first, second and third cut respectively. It was at par with Treatment 5 (100% GR + RDF + 5t ha^{-1} vermicompost) and Treatment 6 (pressmud @ 5.0tha^{-1} + 100% GR + RDF). The data also revealed that the subsurface drainage system did not have a significant impact on the crude fiber content of the CN hybrid. The interaction between the drainage system and the amendments was not significant.

Table 2 Effect of subsurface drainage system and amendments on crude fiber content (%) at various cuttings cutting stages of CN hybrid

Treatments	Cutting 1			Cutting 2			Cutting 3		
	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean
T_1	27.4	27.5	27.5*	27.3	27.4	27.4*	27.2	27.2	27.2*
T_2	27.1	27.3	27.2*	27.0	27.2	27.1*	26.8	27.0	26.9*
T_3	26.0	26.1	26.1*	25.8	26.0	25.9*	25.5	25.9	25.7*
T_4	26.7	26.8	26.8*	26.6	26.8	26.7*	25.7	26.7	26.2*
T_5	26.4	26.5	26.5*	26.3	26.4	26.4*	26.2	26.2	26.2*
T_6	26.3	26.3	26.3*	26.1	26.2	26.2*	25.9	26.0	26.0*
T_7	26.9	27.1	27.0*	26.8	27.0	26.9*	26.8	26.8	26.8*
Mean	26.7	26.8	26.7	26.6	26.7	26.6	26.3	26.5	26.4
	SEd		CD (0.05)	SEd		CD (0.05)	SEd		CD (0.05)
M	0.25		NS	0.10		NS	0.14		NS
T	0.35		0.66	0.31		0.65	0.26		0.53
M X T	0.48		NS	0.43		NS	0.36		NS

* P<0.05 (Significant at 5% level)

4 Discussion

4.1 Effect of the drainage system and amendments on CN hybrid

The provision of the underground drainage system and the application of different amendments levels have considerably improved the height of the CN hybrid grass and varied from 186 to 270, from 136 to 218 and from 125 to 204 cm in the first, second and third cut, respectively, in the drained field. Significantly higher height of the plant recorded in the drained field instead of the non-drained field, due to the improvement of the physico-chemical properties of the soil by the drainage system. Similar crop improvements in plant height in different crops such as maize (Bolton et al., 1982), peanuts (Kolekar et al., 2011), mango (Biharilal & Shrivastava, 2001), coconut (Sousa et al., 2011) under the drainage system was reported by various researchers, findings of these study are in agreement with the result of current study. The improvement in soil aeration, water logging free condition, leaching of soluble salts from the root zone of the crops, improved mineralization and nutrient cycle in the soil, have increased the height of the drained field plant (Balusamy &Udayasoorian, 2016a). In general, the height of the plant is decreased from the first to the last (3rd) stages of cutting of the CN hybrid, both in the drained and undrained field. The decrease in the height of the plant was due to the duration between each cutting stage (first cut 90 days after sowing, second and third cut at intervals of 45 to 50 days) and a decrease in the availability of nutrients between each cutting phase.

In general, organic amendments have positively increased the height of the plant. Application of FYM (12.5 t ha^{-1}) with gypsum requirements and full dose of fertilizer, superior over other organic amendments and control in terms of increasing the height of the plant. The increase in plant height due to the favorable effect of organic fertilizers, which improved soil fertility, physical and chemical environment of the soil, promoting better stabilization, root proliferation, absorption of nutrients and water by the crops (Parameswari, 2013; Behera & Pattanayak, 2016; Dalei et al., 2016).

In the undrained control field (without drainage system and amendments), a lack of plant growth was observed due to the poor physical and chemical properties of the soil *viz.*, reduced soil aeration, waterlogged condition, high pH, EC, ESP, reduced nutrient availability and nutrient absorption by the plant (Mass & Grattan, 1999; Hebsur et al., 2007).

4.2 Green fodder yield

In general, the yield of green forage has decreased from first to last (third) stage of CN hybrid cutting, both in the drained and undrained field, due to the duration (first cut 90 days after planting, second and third cut at intervals of 45 to 50 days) and less availability of nutrients between each cut. The highest yield of green fodder was recorded in the drained field due to the reduction in soil pH, EC, ESP, improvement in water logging free condition, aeration and availability of nutrients for crops (Hebsur et al., 2007). Similarly, several researchers Kornecki et al. (2001), Sharma & Gupta (2006), Yu et al. (2016) also observed an improvement in the plant's performance in the saline-alkaline soil saturated with water due to the provision of a drainage system. Balusamy &Udayasoorian (2016b), observed an increase in plant height, LAI and sunflower seed yield by 52.6% following the adoption of the subsurface drainage system and the application of FYM.

The application of organic amendments together with the effluent irrigation has increased the yield of green forage of the CN hybrid grass. This increase due to the decomposition of organic fertilizers is accompanied by the release of appreciable amounts of CO_2 that dissolve in water to form the carbonic acid which was responsible for releasing appreciable amounts of nutrients from the plants to the soil, which could contribute to higher yields (Bharadwaj & Omanwar, 1994; Sebastian et al., 2009). The application of FYM together with gypsum requirement and full dose of fertilizer has recorded the highest increase in green fodder and dry matter yield due to higher mineralization and nutrient supply by FYM (Shahid et al., 2013; Tadesse et al., 2013). The poor growth and yield characteristics in the control treatment (without amendments and drainage systems) due to the absence of a drainage system should concentrate the soluble salts in the soil profile, impair the availability of nutrients and finally the growth and yield of plants (Zeng & Shannon, 2000).

4.3 Crude protein and crude fiber

In general, the adoption of the drainage system and the application of recommended dose of NPK fertilizer together with gypsum requirement have substantially increased the crude protein content of the CN hybrids grass compared to the undrained field. Better soil aeration, reduced soluble salt concentration, increased microbial activity, nutrient availability and nitrogen uptake by CN hybrid grass could increase the raw protein content. This is in agreement with the findings of Hebsur et al. (2007), Kornecki et al. (2001) and Satyanarayana & Boonstra (2007) who reported that the drainage system effectively reduced flooding, problem of salinity, improved the physico-chemical properties of the soil, availability of nutrients, absorption and growth of crops.

The application of FYM, pressmud, vermicompost, MLSS compost and biochar together with GR and RDF evidently increased the crude protein content. A relatively higher content was recorded in the combination of the FYM treatment together with the gypsum requirement and full dose of fertilizer due to the supply of a high amount of nitrogen and improved the physico-chemical properties of the soil. The combined application of organic and inorganic fertilizers increased the crude protein content of the forage crops. The paper mill effluent is rich in N, which has contributed to the increase in crude proteins. Several studies have reported a significant increase in the crude protein content of sorghum and maize through the application of wastewater (Mohammad et al., 2007; Ghanbari et al., 2007).

The value of crude fiber is an indirect indication of the digestibility of the forage. It is known that the higher the crude fiber content, the lower the digestibility and vice versa. The drainage system showed no influence on the crude fiber content of the CN hybrid grass. The application of organic amendments has significantly reduced the crude fiber content. The reason for the lower content of crude fibers in the organic manure amended plots compared to other controls could be due to the supply of a sufficient amount of organic matter and essential nutrients through the amendments that result in a highly succulent biomass formation as demonstrated by the attributes of biomass growth and yield (Govindasamy & Manickam, 1988; Malarvizhi & Rajamannar, 2001).

Conclusion

The application of organic amendments such as vermicompost, FYM, pressmud, ETP sludge etc. in the drained field increased the height of cumbunapier grass, the content of crude proteins and the total yield of green forage compared to the control field without drainage. Therefore, adoption of a subsurface drainage system and integrated use of organic amendments together with inorganic fertilizers, determine a better improvement in restoring waterlogged saline-alkaline soil, where the irrigation induced salinization and waterlogging limits the crop productivity in the arid and semi-arid regions and specific situation in which the treated effluent is used continuously for cultivation.

Acknowledgments

The authors are thankful to Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore and Tamil Nadu News Print and Paper Limited, Pugalur for the financial and logistics support to carrying out the research.

Conflict of interest

All the authors declare that there is no conflict of interest.

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