

Original Research Article

Grewia tenax for Sustainable Agroforestry Farming in Saline Soils of Khartoum State of Sudan

Abstract

Intercropping of cow pea (*Vigna unguiculata*) with multipurpose tree in terms of *Grewia tenax* was carried out under saline soils in south of Khartoum State in Sudan. The objectives were to investigate the performance of trees species under sub-irrigation regime in saline soils as well as to find out most agro forestry system suitable for these soil types. The experiment was carried out during period of March to November 2017 in terms of completely randomized block design with 3 replicates. The treatments were *Grewia tenax* tree that fixed at spacing of 4x4 m versus cow pea which sown at one and 1.5 m apart from the tree trunk at 25 cm and 50 cm as inter and intra rows spacings besides sole tree and crop as controls. Soil samples were taken at depths of 0-10 cm, 10-30 cm, 30-60 cm and 60-100 cm from soil profile of 1x1 m and 1.5 m depth and its chemical and physical properties were analyzed.

Grewia tenax trees parameters were measured in terms of tree height, tree collar diameter and tree crown diameter. While cow pea crop parameters were determined in terms of straw weight and crop yield per hectare as well as land equivalent ratio. The data revealed that; soil chemical properties for pH, EC ds/m, CaCO₃, SAR and ESP were increased with increasing soil depths for other chemical properties in terms of Nitrogen content, Organic carbon and C/N ratio did not differ with respect to soil layers. Meanwhile the total average tree growth mean in terms of tree height, tree collar diameter and tree crown diameter were higher under intercropping than in sole trees, similarly for crop straw weight. Crop yield did not differ between the crop spacing and the control. Partial LER was higher under straw weight than for yield and the total LER was advantageous particularly under GS1 which indicates the superiority of intercropping than monocropping in this saline soil.

Key words: Intercropping, *Grewia tenax*, cow pea, Land equivalent ratio, Saline Soil

Introduction

Agro forestry is a land use system that deliberately incorporates integration of forests into agricultural lands or agricultural lands into forests. Therefore, its role is to obtain proper and wise management of natural resources in terms of sustainability to enhance productive means of lands for the sake of human and animals (Baumer, 1986). Thereby using of some agro forestry systems or techniques will maintain or improve the farming systems (Lundgren, 1983, Raintree, 1984, Julius *et al.* 2017). Thus introduction of multi- purpose trees such as nitrogen fixing trees will enhance soil fertility. Besides that it can ameliorate soil physical properties as stated by (Hussein *etal.*, 1998). In this regard, introducing of some other multi- purpose trees in marginalized soils such as saline soils will maintain or increase their efficiency in terms of productivity and sustainability (Vandebeldt, 1990; NasreAldinet *al.*, 2010).

Sodicity occurs when soluble salts (usually sodium) are elevated in soil and water mainly in arid and semiarid areas. Sodic soils can be formed by natural processes such as the weathering of mineral rocks (called primary salinity) because there is often inadequate rainfall or drainage to leach the salt down (Carrow and Duncan, 2011). Besides that secondary salinity can occur as a result of human interventions in agricultural areas. For instance due to removal of native vegetation and perennial shrubs and trees of deep roots and replacing them with shallow rooting crop plants which cause the underground water to rise and move the salts up to the soil surface. Salinity can inhibit the processes that include protein synthesis and can affect the older leaves at high level of toxicity, thus let the older leaves to die or to reduce their photosynthetic area (Panming, 2011). However, Armitage (1984) reported that vast tracts of arid and semi arid areas in the world are subjected to desertification due to water deficit associated with salinity.

Grewia tenax is a multipurpose tree locally known as (Geddiem) is a drought resistant tree or shrub that reaches up to 2 m in height. It predominates in arid and semi arid areas. In Sudan it exists in many areas such as in Khartoum State (Elamin, 1990). However, it tolerates many soil types such as rocky, sandy and clay as well as saline soils. Also it found in many elevations from 0-1500 m and it withstands cold weather and heat. The tree has many uses; as its edible fruits which contain high iron content and the leaves that browsed by animals in arid and semi arid zones ; which considered resistant to repeated browsing by animals (Elamin, 1990 and Vegot, 1995).

Cow pea (*Vigna unguiculata*) is a summer annual legume, it widely grown in Africa, Latin America, South eastern Asia and Southern United States. The plant types are often categorized as erect, semi-erect, prostrate (trailing), or climbing. Cow pea is mainly used as grain crop in human diet or as fodder for animals feed and as vegetable, due to its nutritious seeds. However, cow pea is rich with many ingredients; protein content that amounts to 25%, carbohydrate 64% and Fiber 6.3% as well as other components such as fat, Thiamine, Riboflavin and Niacin. Cow pea is drought resistant crop than other common beans and it grows under both irrigation and non irrigated regions. Generally it has strongly taproots system that can reach to depth of 95 inches in 8 weeks after planting. Cow pea responds to a variety of soils and soil conditions and it is suitable for pH ranges between 5.5 and 6.5. And it can be harvested in period of 60-90 days according to varieties and its purposes of planting (Davis *etal.* 1991).

Therefore introduction of this agro forestry system in terms of intercropping of *G.tenax* with cow pea in the saline soils will improve the potentiality of these soils to be productive as well as to increase the income of the farmers. Also will reduce the hazardous effects of these soils and will halt desertification due to misuse of the lands as a result of bad practices. Thus the objectives of this experiment were; to find out tree growth performance under sub irrigated regime, to find out an agro forestry model that suits saline soils of Khartoum State and to investigate the effect of trees spacing on some field crops yields in saline soils.

Materials and Methods

Site:

This experiment was conducted in Forestry and Gum Arabic Research Centre Farm in Soba, south of Khartoum State in Saline soils during the period of March 2017 to November 2017. (Longitude 30° 30' E, Latitude: 15° 30' N). The general climate of the area is of semi arid type and characterized by very low erratic rainfall (164 mm per annum), occurring mostly between July and September. Average annual temperature is about 30° C; the hottest months are May – June (Temperature is 42° C and the coldest months are December –January (Tem is 10° C). The average relative humidity is 21%, it drops to about 13% during the spill of the hottest winds in March and April and rises to 42% during the wetter period in August (Khartoum Metrological Station data). The vegetation is composed of *Prosopis chilensis*, *Acacia seyal*, *Balanites aegyptiaca*, *Capparis decidua* and *Grewia tenax*. The train is flat with clay soil (Vertisol). The soil profile is markedly differentiated and shows the following general features:

Dark grayish brown soil colour, texture is clay loam over clayey, moderate medium and fine sub-angular blocky structure over weak coarse medium and fine sub angular blocky structure over massive, moderately to strongly calcareous soil matrix. Thus slightly hard dry, friable moist, firm moist and stickymassive and few sing sandgrains, few CaCO₃ white soft aggregates, few hair roots and decayed roots, strongly calcareous. Soil pH is alkaline ranging between 7.6, 7.8, 7.9 and 8.6 for the following layers 0-10cm, 10-30 cm, 30-60 cm and 60-100 cm respectively as indicated in tables one & 2.

Table1: Soil chemical properties for EC, Caco3, SAR, ESP, pH paste, N%, OC% and C/N at different depths.

Depth cm	EC ds/m	CaCO ₃ %	SAR	ESP	pH paste	N %	O.C %	C/N Ratio
0 - 10	2.0	1.8	9	10	7.8	0.810	0.485	6
10 – 30	2.2	2.1	10	11	8.0	0.820	0.486	6

30 – 60	2.5	2.3	10	11	8.4	0.830	0.486	6
60 - 100	16.1	5.2	30	30	9.1	0.820	0.486	6

Table 2: Soluble Cations, Anions, Excl. cal, Available Pp.p.m and CEC.

Depth cm	Soluble Cations			Soluble Anions		Excl. cal		Available P	CEC
	Na	Ca	Mg	CL	HCO ₃	Na	K	p.p.m	
0 - 10	12.1	8.2	1.8	10.1	1.1	11.3	0.50	2.3	35
10 – 30	14.2	10.1	2.1	11.3	1.3	11.5	0.55	2.1	36
30 – 60	17.3	10.6	2.3	13.1	1.3	19.5	0.61	3.4	39
60 - 100	75.2	12.4	3.1	130.1	3.1	128.1	0.72	1.5	45

This experiment was conducted in Forestry and Gum Arabic Research Centre Farm in Soba, south of Khartoum in Saline soils during the period of March 2017 to November 2017. Seedlings of tree species in terms of *Grewia tenax* (*Geddum*) were used at fixed spacing of 4x4 m. The seedlings of one year old were obtained from the Forestry and Gum Arabic Research Centre Nursery and were transplanted under irrigation system in March 2017. And the seedlings were watered in the first stage consistently (once a week) from permanent water supply source from March to July; then from rainfall during the wet season beside the permanent water source from July to November. Improved cow pea (*Vigna unguiculata*), variety Ain Algazal was introduced from Alobeid Agricultural Research Station and was intercropped with the trees as summer crop. The experiment was laid out in terms of completely randomized block design with three replicates. The main treatment was the tree species *Grewia tenax* (*G.tenax*) at spaced at 4x4 m versus cow pea crop that intercropped at two spacings from the tree trunk part namely; 1m (GS1) and 1.5m (GS2). The cow pea crop was sown in first of August at spacing of 50x25 cm, 3 seeds per a hole. In addition to sole crop and trees were planted as controls. The agricultural practices in terms of ploughing and weeding were carried out for trees and crop as necessary.

The experiment plot size was 12x8 m for each treatment and the number of the trees per a treatment is 12 trees. Therefore the total experiment area size is 225*150 square metre and number of trees per ha is 1250 trees.

Parameters that measured for the trees were:-

Tree height in cm, tree collar diameter in cm, Tree crown diameter in m were measured monthly and started after well establishment of the trees in May.

Crop parameters

The parameters that measured for the cow pea crop were; crop biomass (straw) weight kg/ha and crop yield kg per ha.

Land Equivalent Ratio (LER)

Land Equivalent Ratio (LER): Fractions of intercropped crops divided by sole crops was used as measurement for the agro forestry efficiency. Therefore the value is more than one that indicates the advantage of intercropping. And vice versa for the values that are less than one which means mono-cropping is superior than intercropping as stated by Sullivan (1998).

Statistical analysis for the generated data was done by using Genstat software. The differences between the treatments means were determined by using ANOVA Tables, where LSD (Least Significant Differences at 5% level and 1% level).

Results

Tree Growth Measurements

***Grewia tenax* tree height**

Highly significant differences were obtained between spacings with respect to tree height within the months. Thus it was highly significant in May when compared control with other treatments. In October it was recorded highly significant when contrasted GS1 and GS2 with control. Similarly in November it recorded higher value for intercropped treatments compared with control one as indicated in table 2. Generally the average mean growth in terms of tree height is higher under GS1 then following by GS2 spacing when compared with control that given the least growth as indicated in table 3.

Table 3: Tree height for *G.tenax*(cm) for the following months (May, June, July, August, September, October and November 2017).

Treatment	Months							
	May	June	July	August	September	October	November	Average mean
GS1	39.5±2.7 7a	54.6±0.7 a	92.1±8. 7a	120.4±13 .2a	163.2±11 .1	185.4±12 .04	188.8±11. 86	120. 6

					a	ab	a	
GS2	46.4±2.7 7a	59.1±0.7 a	90.5±8. 7a	120.4±13 .2 a	148.5±11 .1 a	171.3±12 .04 a	180.7±11. 86 a	116. 7
Control	51.3±2.7 7ab	49.7±0.7 a	84.9±8. 7a	110.4±13 .2 a	135.5±11 .1 a	167.9±12 .04 a	167.3±a11 .86 b	109. 6
Sig. level	** 0.001	ns 0.087	ns 0.118	ns 0.43	ns 0.076	** 0.016	* 0.018	
Pro	8.73	15.56	18.6	44.18	13.5	37.95	37.38	
CV%	12.9	15.7	27.47	20.7	34.82	12.0	11.1	
LSD								

Means followed by the same letters are not significantly different at 5% or 1% level. Ns=not significant, G=*Grewia tenax*, S1= crop cultivated one metre from tree trunk. S2=crop cultivated 1.5 metre from tree trunk.

***Grewia tenax* collar diameter**

Similar results were obtained for tree collar diameter in May it was highly significant under treatments than in control. Also it was been significant in June, July and September when compared with the other months as shown in table 3. Thus the collar diameter was higher in intercropped treatments under GS1 in June, July and September than in the other treatments. Similarly the total average mean collar diameter was higher in spacing 1 (GS1) than GS2 and the control that of the same value as indicated in table 4.

Table 4: Tree collar diameter (cm) for *G. tenax* for the following months (May, June, July, August, September, October and November 2017).

Treatment	Months							Average mean
	May	June	July	August	September	October	November	
GS1	0.53±0.0 4a	7.16±4.5 c	13.06±1. 6a	14.18±3. 2a	15.12±1.3 a	16.7±3. 4a	17.99±3. 4a	12.1
GS2	0.66±0.0 4a	3.05±4.a	11.26±1. 6a	11.58±3. 2a	13.43±1.3 a	14.0±3. 4a	15.3±3.4 a	9.9
Control	0.44±0.0 4b	5.07±4.5 ab	11.13±1. 6a	11.83±3. 2a	12.44±1.3 a	13.5±3. 4a	14.87±3. 4a	11.5

Sig. level	**	*	*	ns	*	ns	ns
Pro	0.001	0.026	0.058	0.7	0.034	0.377	0.206
SE±	9.3	23.7	29.8	32.3	19.1	44.0	
CV%	0.084	2.53	5.17	7.13	4.17	10.75	31.55
LSD							7.46

Means followed by the same letters are not significantly different at 5% or 1% level. *ns*=not significant, *G*=*Grewia tenax*, *S1*= crop cultivated one metre from tree trunk. *S2*=crop cultivated 1.5 metre from tree trunk.

Grewia tenax Crown diameter

Tree crown diameter was highly significant in September and November than in the other months. Thus crown diameter was been higher under *GS2* and *GS1* in September, while it was highly significant in November as indicated in table 5. Meanwhile the total average mean crown diameter was been higher in intercropping than in control as indicated in Table 5.

Table 5: tree crown diameter for *G.tenax*(m) for the following months (September, October and November 2017

Treatment	Months			
	September	October	November	Average mean
GS1	4.79±0.0.53a	5.59±2.13a	6.36±0.511a	5.58
GS2	4.82±0.0.53ab	5.49±2.13a	6.27±0.511a	5.53
Control	4.08±0.0.53a	4.72±2.13a	4.35±0.511b	4.38
Sig. level	**	ns	**	
Pro	0.003	0.168	0.007	
SE±	17.0	48.9	18.0	
CV%	1.173	4.74	1.61	
LSD				

Means followed by the same letters are not significantly different at 5% or 1% level. *Ns*=not significant, *G*=*Grewia tenax*, *S1*= crop cultivated one metre from tree trunk. *S2*=crop cultivated

Cow pea parameters

Cow pea biomass (straw) was been significant under intercropping when compared with control particularly in *GS1*. While cow pea yield kg/ha was not significantly differed with respect to distances from trees trunk as indicated in table 6.

Table 6: Intercropped cowpea with *G.tenax* biomass (straw) weight (kg/ha) and yield (kg/ha).

Treatments	Cow pea biomass (straw) weight	Cow pea yield kg/ha
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	kg/ha	
GSI	1747±491.9a	566±208.8a
GS2	1385±491.9b	293±208.8a
Control	603±491.9d	384±208.8a
Sig. level	*	ns
Pro	0.052	0.132
SE±	39.0	57.4
CV%	1134.4	481.5
LSD		

Means followed by the same letters are not significantly different at 5% level. Ns =not significant, G=*Grewia tenax*, S1= crop cultivated one metre from tree trunk.S2=crop cultivated at 1.5 metre from tree trunk.

Land equivalent Ratio (LER)

The partial land equivalent ratio was advantageous for straw weight; particularly under GS1 than GS2. For cow pea yield, it was advantageous under GS1 unlikely in GS2 as indicated in table 7. But however the total LER was advantageous under this agroforestry system as indicated in table 7.

Table 7: Land Equivalent Ratio for cow pea intercropped with *G. tenax*.

Parameter	Pure cow pea crop kg/ha	Intercropped cow pea with <i>G. tenax</i> kg/ha	LER
Straw			
GS1	603	1747	2.9
GS2		1385	2.3
Average			2.6
Crop yield			
GS1	384	566	1.5
GS2		293	0.8
Average			1.3
Total LER			3.9

Discussion

In spite of the fact that, *Grewia tenax* is a multi -purpose tree species of natural existence and predominates in many parts of the Sudan in drier areas such as Khartoum State. Besides, it has different shapes; can be shrubby or scramble and can reach 2 m in height (Baumer, 1983, Elamin, 1990). Besides that in this experiment; the trees were transplanted of one year age and under soil salinity ranged between, 7.6-8.6 which classified as alkaline soil as indicated in tables (1&2). As well as the site received consistent watering during the growing season and the tree performance growth was monitored periodically throughout the first stage of growth. *G. tenax* tree height was been higher under intercropping, that probably due to respond of *Grewia tenax* to consistent watering in addition to the good cultural practices that taken place, likewise for tree

collar diameter. Besides that, it could be attributed to the fact that, *Grewia tenax* is a fast growing tree species that can develop fast. In addition, cow pea has a tap root and could not be affected by trees of shallow roots. This in agreement with Ong *et al* (1996) who attributed the major problems of agroforestry in the dry land to competition between herbaceous crops and woody perennials in the sharing resources. However, these sharing resources were appeared in above and below ground competitions. Therefore, the competition will be severe; if the selected trees and crops are of the similar characteristics such as trees and crops have shallow roots systems. Otherwise, trees of tap roots system and herbal crops of shallow roots should be selected as stated by Nair (1993). Whereas in humid areas; however the above ground competition is dominant particularly light interception that adversely affects plant photosynthesis. Thus, the amount of light that intercepted depends on tree canopy, spacing and species as stated by Kessler and Breman (1991).

Meanwhile, tree crown diameter was been significant in September and November probably due to the fact that; *Grewia tenax* is a shrubby and is fast growing tree species with good coverage. This in agreement with (Baumer, 1983, Elamin, 1990) who reported that *Grewia tenax* is a shrub and can be scrambled and predominates in drier areas such as many parts of the Sudan viz. drier areas like Khartoum State. In this experiment the trees were transplanted of one year age under soil salinity ranged between, 7.6 and 8.6 which classified as alkaline soil as well as the site was received consistent watering during the growing period. Thus the site gave good site conditions for the tree to be well established.

Cow pea biomass (straw) weight was higher under narrow spacing (1m) apart from *Grewia tenax* that probably due to the minor effect of intercropping under this agro forestry system. Thus the competition for water is less than for other resources. Also the effect of shading is minor because the model is in the early establishment stage. Similar results were obtained by Raddad and Luukkanen (2007) who stated under early stage the competition between crops and trees might be less. Besides that, the site has more salinity with increasing depths from the top soil surface. Hence, the competition for below ground resources should be minor under this agro forestry system. Nevertheless, this tree is drought resistant and tolerates salinity (Baumer, 1983; National Academy, 1980). Whereas Parandiyal *et al.* (2008) stated that some trees have adverse impact on the associated field crops, particularly when *Acacia nilotica*, *A.indica* and *Albizia lebbek* were grown under boundary with castor and pigeon pea.

LER is advantageous under this agro forestry system and it was more advantageous under intercropping of *Grewia tenax* with cow pea in narrow spacing (1m) than wide spacing (1.5 m). Hence, agro forestry system can be advantageous over conventional agricultural and forest production methods. Thus it can offer increased productivity, economic benefits and more diversity in the ecological goods and services that provided as stated by (Kitalyi *etal.* 2009, Nasre Aldin *etal.* 2011, Lasina, 2017).

Conclusion

So it can be concluded that tree growth parameters did not affect in the early stage in this agroforestry system. Thus the total average mean of tree height, collar diameter and tree crown

diameter was higher under intercropping particularly GS1. LER is advantageous under this agroforestry system particularly for straw and yield weight in GS1.

So based on these results it is recommended that intercropping can be carried out between *Grewia tenax* and cow pea under this saline soil particularly under narrow spacing (1m). That in order to secure farmers food security as far as to obtain fodder for animals and to produce crop yield of highly nutritious value. So through this agroforestry system farmers can safeguard their income and halts desertification as well as sequester carbon under saline soils.

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