***Original Research Article***

*Grewiatenax* for Sustainable Agroforestry Farming in Saline Soils of Khartoum Stateof Sudan


Abstract

Intercropping of cow pea (*Vigna unguiculata*) with multipurpose treein 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 *Grewia tenax*trees under sub-irrigation regime in saline soils as well as to find out most agro forestry system suitable for saline soil. 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 crop which sown at one and 1.5 m apart from the *Grewia tenax*tree trunkat 25 cm and 50 cm as inter and intra rows spacings besides sole *Grewia tenax*tree andcow pea crop ascontrols. 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.

*Grewiatenax*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 , while 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 *Grewia tenax*tree growth means in terms of tree height, tree collar diameter andtree crown diameter were higher under intercropping than in sole trees, similarly for cow pea crop straw weight.Cow pea yield did not differ between the intercropped plots 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 mono-cropping 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 isto obtain proper and wise management of natural resources in terms of sustainability to enhanceproductive means of lands for the sake of human and animals (Baumer, 1986). In this respect, by such means farmers can diversifying their cropping systemsby using integrated farming systems which aim at increasing the potential of the limited resources in terms of land and water. Thus farmers can achieve the goal for food security, nutritional security, income growth, poverty alleviation, job creation and wise use of water and land as stated by (Hedge *et al*., 2003). Therefore using of such agro forestry systems or techniques will maintain or improve the farming systems (Lundgren, 1983; Raintree, 1984; Julius*et al*., 2017). In this regard, introducingof multi- purpose trees such as nitrogen fixing species will enhance soil fertility as wellas ameliorate soil physical properties besides sustain the existing farming systems that previously depend on mono-culture. However, mono-cropping has depleted the soil and the lands in arid zones by its intensive cultivation and over utilization and denudation of the forests' lands which led to desertification.Thus introducing of multi- purpose trees in marginalized soils such as saline soils will maintain and increase their potentiality and efficiency in terms of productivity and sustainability (Vandebeldt, 1990; Hussein *etal*., 1998; NasreAldin*et 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 instancedue 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 inhabit 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) reportedthat 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 reachesup to 2 m in height. It predominates in arid and semi arid areas. In Sudan itexistsin many areassuch 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; Vgot, 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 animalsfeedand as vegetable,due to its nutritious seeds.However, cow pea is

rich with many ingredients;protein content that amounts to 25%,carbohydrate64% 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 none 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 pHranges between 5.5 and 6.5. And it can be harvested in period of 60-90 days according to varietiesand its purposes of planting (Davis *etal*., 1991).

Therefore introduction of thisagro forestry system in terms of intercropping of *Grewia 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 *Grewia tenax*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 *Grewia tenax*trees spacing on cow pea crop yield 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 30º 30′ E, Latitude15º 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 30º C; the hottest months are May – June (Temperature is 42º C and the coldest months are December –January (Temperature is 10º 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 $CaCO_3$ 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 respectivelyas indicated in tables one & 2.

Table1: Soil chemical properties at different depths in the experiment site in 2017.

| Depth | EC | $CaCO_3$ | SAR | ESP | pH paste | N | O.C | C/N |
|---|---|---|---|---|---|---|---|---|
| cm | ds/m | % | | | | % | % | 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 |

EC (Exchangeable Cation), SAR(Sodium absorption Ratio), O.C(organic carbon).

Table 2: Soil chemical properties in the experiment site in 2017.

| Depth cm | Soluble Cations | | | Soluble Anions | | Excl. cal | | Available P p.pm | CEC |
|---|---|---|---|---|---|---|---|---|---|
| | Na | Ca | Mg | CL | $HCO_3$ | Na | K | | |
| 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 |

CEC (Cation Exchangeable Capacity).

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 Grewia *tenax* tree *(Geddum)* were used at fixed spacing of 4x4 m. Thus seedlings of *Grewia tenax* 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 *G.tenax*seedlings were watered at the first stage consistently (once a week) from permanent water supply source from March to July;besides rainfall during the wet season from July to November. Improved cow pea (*Vigna unguiculata*), variety Ain Algazal was introduced from Alobeid Agricultural Research Station and was intercropped with the *G.tenax*trees as summer crop. The experiment was lied out in terms of completely randomized block design with three replicates. The main treatment was the *Grewia tenax*trees(*G.tenax*) at spaced at 4x4 m versus cow pea crop that intercropped at two spacings from the tree trunkapart 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 cow peacrop and *G.tenax*trees were planted as controls. The agricultural practices in terms of ploughing and weeding were carried out for both the trees and the crop as necessary.

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

**Parameters that measured for the *G.tenax*trees were:-**

*G.tenax* tree height in cm, collar diameter in mm, crown diameter in m were measured monthly and started after well establishment of *G.tenax*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 GENSTATSoftware. 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 (cm)**

Highly significant differences wereobtained between spacings with respect to *G.tenax*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.Genrally the average mean growth in terms of *G.tenax*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: *Grewia tenax* tree height (cm) for the following months (May, June, July,August, September, October and November 2017.

| Treatment | Months | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Tree height in cm | May | June | July | August | September | October | November | Average mean |
| GS1 | 39.5±2.8a | 54.6±0.7 a | 92.1±8.7a | 120.4±13.2 a | 163.2±11.1 a | 185.4±12.0 4 ab | 188.8±11.86 a | 120.6 |
| GS2 | 46.4±2.8a | 59.1±0.7 a | 90.5±8.7a | 120.4±13.2 A | 148.5±11.1 a | 171.3±12.0 4 a | 180.7±11.86 a | 116.7 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Control | 51.3±2.8ab | 49.7±0.7 a | 84.9±8.7a | 110.4±13.2 A | 135.5±11.1 a | 167.9±12.0 4 a | 167.3±a11.8 6 b | 109.6 |
| CV% LSD | 8.73 12.9 | 15.56 15.7 | 18.6 27.47 | 44.18 20.7 | 13.5 34.82 | 37.95 12.0 | 37.38 11.1 | |

Means followed by the same letters are not significantly different at 5% or 1% level. GS1=Cow pea sown at 1m from *Grewia tenax*tree trunk, GS2=Cow pea sown at 1.5 m from Grewiatenax tree trunk.

### *Grewia tenax*collar diameter (mm)

Similar results were obtained for *G.tenax* 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 4.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 (GS1)than GS2 and the control that have the same value as indicated in table 4.

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

| Treatment | Months | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Tree collar diameter in mm | May | June | July | August | September | October | November | Average mean |
| GS1 | 0.53±0.04a | 7.16±4.5c | 13.06±1.6a | 14.18±3.2a | 15.12±1.3a | 16.7±3.4a | 17.99±3.4a | 12.1 |
| GS2 | 0.66±0.04a | 3.05±4.a | 11.26±1.6a | 11.58±3.2a | 13.43±1.3a | 14.0±3.4a | 15.3±3.4a | 9.9 |
| Control | 0.44±0.04b | 5.07±4.5ab | 11.13±1.6a | 11.83±3.2a | 12.44±1.3a | 13.5±3.4a | 14.87±3.4a | 11.5 |
| CV% LSD | 9.3 0.084 | 23.7 2.53 | 29.8 5.17 | 32.3 7.13 | 19.1 4.17 | 44.0 10.75 | 31.55 7.46 | |

Means followed by the same letters are not significantly different at 5% or 1% level. GS1=Cow pea sown at 1m from *Grewia tenax* tree trunk, GS2=Cow pea sown at 1.5 m from *Grewia tenax* tree trunk.

### *Grewia tenax* crown diameter (m)

*G.tenax* tree crown diameter was highly significant in September and November than in the other months. Thus *G.tenax*crown diameter was been higher under GS2 and GS1in 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: *Grewia tenax*tree crown diameter (m) for the following months (September, October and November 2017.

| Treatment | Months | | | |
|---|---|---|---|---|
| Tree crown diameter in cm | 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 |
| CV%<br>LSD | 17.0<br>1.173 | 48.9<br>4.74 | 18.0<br>1.61 | |

Means followed by the same letters are not significantly different at 5% or 1% level. GS1=Cow pea sown at 1m from *Grewia tenax* tree trunk, GS2=Cow pea sown at 1.5 m from *Grewia tenax* tree trunk.

**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 *G.tenax*trees trunk as indicated in table 6.

Table 6: Intercropped cowpea with *Grewia tenax* biomass (straw) weight (kg/ha) and yield (kg/ha) in 2017.

| Treatments | Cow pea biomass (straw) weight kg/ha | Cow pea yield kg/ha |
|---|---|---|
| GSI | 1747±491.9a | 566±208.8a |
| GS2 | 1385±491.9b | 293±208.8a |
| Control | 603±491.9d | 384±208.8a |
| CV%<br>LSD | 39.0<br>1134.4 | 57.4<br>481.5 |

Means followed by the same letters are not significantly different at 5% or 1% level. GS1=Cow pea sown at 1m from *Grewia tenax* tree trunk, GS2=Cow pea sown at 1.5 m from *Grewia tenax* tree trunk.

**Land equivalent Ratio (LER)**

The partial land equivalent ratio was advantageous for straw weight; particularly under GS1than 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 *Grewia tenax*.

| Parameter | Pure cow pea crop kg/ha | Intercroppedcow pea with *Grewia tenax*kg/ha | LER |
|---|---|---|---|
| Straw<br>GS1<br>GS2<br>Average | 603 | 1747<br>1385 | <br>2.9<br>2.3<br>2.6 |
| Crop yield<br>GS1<br>GS2<br>Average | 384 | 566<br>293 | <br>1.5<br>0.8<br>1.3 |
| Total LER | | | 3.9 |

GS1=Cow pea sown at 1m from *Grewia tenax* tree trunk, GS2=Cow pea sown at 1.5 m from *Grewia tenax* tree trunk.

**Discussion**

It is worth mentioning that the site received consistent watering during the growing season. Besides that, the *G.tenax*tree performance growth was monitored periodically throughout the first stage of growth.In this regard, the significance of *Grewia tenax*tree height under intercropping,might be attributed to its respond to consistent watering as well as to good cultural practices that taken place, likewise for *G.tenax*tree collar diameter. Furthermore, it could be related to the fact that,*Grewia tenax* is a fast growing tree that can develop faster under these conditions. In addition to that,no interface with cow pea could be observed, with respect to *G.tenax* growth. Hencecow pea has a tap root system and could not affect trees of shallow roots such as *G.tenax*. This in agreement with Ong e*t al*. (1996) who attributed the major problems of agroforestryin the dry landsto 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 more 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 herbaceous crops of shallowrootssystem should be selected to sustain the farming system and to minimize the effect of interface as stated by Nair (1993). In humid areas,above ground competition is dominant particularly light interception which adversely affects plant photosynthesis and finally reduced its yielding ability in a sustained way. In this regard, trees phonology and characteristicsmight properly identify the amount of light that intercepted as well as other trees'factors such as their canopy, species and spacing as stated by Kessler and Breman (1991).

Meanwhile, the significant in *G.tenax*tree crown diameter in September and November was probably due to the fact that; Grewia *tenax* is a shrubby and of fast growing habit with good coverage. Similarly (Baumer, 1983, Elamin, 1990) reported that *Grewia tenax*is a shrub and can be scrambled and predominatesin drier areas.

The significant of cow pea biomass (straw) weight under narrow spacing (GS1) might be probably due to the minor effect of competition under this agro forestry system. Thus the competition for water is less than for other resources under this condition as a result of consistent watering of the site by both perennial water supply and rainfall. Also it could be related to the minor effect of shading under this study,because the model in its early establishment stage. Similar results were obtained by Raddad and Luukkanen (2007) who stated under early stage of intercropping the competition between crops and trees might be minor.Nonetheless, cow pea is sensitive to high level of salinity as was shown under this study. SimilarlyDavis *etal*. (1991) reported that cow pea crop is sensitive to high level of salinity; thus it is suitable for pH ranges between 5.5 and 6.5. Besides that it was intercropped with *G.tenax*treethat drought resistant andcan tolerates salinity (Baumer, 1983; National Academy, 1980). Despite that,other trees have adverse impact on the associated field crops such as *Acacia nilotica*, *Azadirachtaindica* and *Albizzia lebbeck* whengrown under boundary with castor and pigeon peaas stated by Parandiyal *et al*. (2008).

LER is advantageous under this agro forestry system particularly under narrow spacing (GS1) than widerspacingone (GS2).Hence, agro forestry system is advantageous compared to conventional agricultural and forest production methods. Therefore, it could be expected to increase food security, nutritional status of the farmers, alleviating poverty and increasing income. Besides providing job and reducing unemployment as well as sustaining the farming system by reforestation of marginal soils to secure landsproductivity, economic benefits and

more diversity in the ecological goods and services that provided as stated by (Hedge *et al*., 2003; Kitalyi *etal*.2009; Nasre Aldin *etal*., 2011; ,Lasina ,2017).

## Conclusion

The *Grewia tenax*tree growth parameters did not be affected in the early stage in this agroforestry system. Thus the total average means of *G.tenax*tree height, collar diameter andcrown diameterwerehigher under intercropping particularly GS1. LER is advantageous under this agroforestry system particularly for straw and yield weight in GS1.Soil chemical properties namely; pH, pH, EC ds/m, CaCo3, SAR and ESP were increased with increasing soil depths. While Nitrogen content, Organic carbon and C/N ratio did not differ with respect to soil layers.

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)under semi irrigated regime. That is probably to secure farmers food,to obtain fodder for animals and to produce crop yield of highly nutritious value. So through this agroforestry system farmers can sustain and safeguard theirlivelihood and halt desertification as well as sequester carbon under marginal soils such as saline soils.

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