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Research ARTICLE

Intercropping cowpea (*Vigna unguiculata*) with Ziziphus spina christi on irrigated saline soils of Khartoum State, Sudan

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ABSTRACT

Intercropping cowpea (Vigna unguiculata) with Ziziphus spina christi was carried out under the saline soils south of Khartoum State. The objectives were to find out the most appropriate agroforestry system that can suit these soil types of the semi-arid zones of Sudan as well as to investigate the performance of the tree species in terms of their growth under a supplemental irrigation regime. The study was carried out during the period of March to November 2017 using a randomized complete block design experiment with 3 replicates. The woody component Ziziphus spina christi spaced at 4x4 m and the crop was cowpea which was sown relative to tree trunks, namely at 1 m (S1) and 1.5 m (S2) apart from the trunks. Cowpea was sown at inter and intra-row spacings of 50 cm and 25 cm, respectively. In addition, some trees and pure crops stands were incorporated using the above spacing as controls. Soil samples were taken at depths of 0-10 cm, 10-30 cm, 30-60 cm, and 60-100 cm from an excavated soil profile (1x1 m and 1.5 m deep) to determine the soil's physical and chemical properties. The measured tree parameters for Z. spina christi were namely tree height, tree collar diameter, and tree crown diameter. The Cowpea crop parameters determined were biomass of straw and yield per hectare. Accordingly, the land equivalent ratio was calculated. The data revealed an increase in tree collar diameter which was higher under the wider spacing (1.5 m) as compared to the other (1 m) spacing and the control. Cowpea straw biomass recorded significant differences under the intercropping system as compared with the control, whereas crop yield did not record any significant differences. There was an increase in LER of 1.3 and 3.3 under the wider spacing for both crop and straw yields, respectively. Overall, this agroforestry system has resulted in the provision of both foods for farmers besides fodder for their animals.

Keywords: Agroforestry, cowpea, intercropping, LER, saline soil, *Ziziphus spina christi*,

INTRODUCTION

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) and because there is often inadequate rainfall or drainage to leach the salt down [4]. In addition to this type of salinity, secondary salinity can occur from human interventions in agricultural areas. For instance, by removal of native vegetation and perennial shrubs and trees of deep roots and replacing them with shallow rooting crop plants causes the underground water to rise and move the salts up to the soil surface.

Salinity inhibits the processes that include protein synthesis but if salinity is high to toxic levels the older leaves die or reduce their photosynthetic area [15]. Armitage[1] reported that vast tracts of arid and semi-arid areas in the world are subjected to desertification due to water deficit associated with salinity.

Agroforestry is a land use system that incorporates the deliberate integration of forests into agricultural lands as stated by Baumer [3]. Therefore, its function is to improve the management of natural resources in terms of protective or productive means for the lands for the benefit of humans and animals. Thereby, some agroforestry techniques/ systems would maintain, improve and sustain the farming systems [9,22,14]. Moreover, using multi-purpose trees such as nitrogen-fixing trees will improve or increase soil fertility. In addition, it should ameliorate soil's physical properties as stated by [10]. Hence, introducing some other multi-purpose trees in marginalized soils such as saline soils will maintain or increase their efficiency in terms of productivity and sustainability [25,18].

Ziziphus spina christi locally known as Sidr is a multipurpose tree that predominates in many ecological zones and can reach about 9 meters in height. It is characterized by pale grey bark and spiny leaves. The tree is evergreen in wet areas and drops its leaves in dry areas with less water. It flowers in August to December and bears fruits in November. It prefers some soil types mainly, alluvial, clay, and saline soils. It has a tap root that has extraordinary regenerative power, can tolerate heat, and is drought hardy. The tree has many uses such as sources of timber, fencing, and walking sticks, and the branches are used for building thatched houses and thorn hedges. The fruit is edible, the leaves can be grazed by animals and the wood provides good charcoal [23,3].

Cowpea (*Vigna unguiculata*) is a summer annual legume that is widely spread over all continents. Cowpea is mainly used as a grain or fodder crop to feed humans or animals. The seeds are nutritious, containing 25%, 64%, and 6.3% of protein, carbohydrate, and fiber, respectively as well as other components such as fat, thiamine, riboflavin, and niacin. Cowpea is a drought resistant crop when compared with other common beans and can be grown under both irrigation and non-irrigated regions. It is generally strongly tap-tap-rooted and the root depth can reach up to 95 inches in 8 weeks after planting. Cowpea tolerates many soils and it is suitable for pH that ranges between 5.5 and 6.5. Cowpea can be harvested in 60-90 days according to variety and the purpose of planting [6].

The objectives of the experiment were; to find out an optimum agroforestry model that can suit the saline soils of Khartoum State, agroforestry, to determine the effect of tree spacing on cowpea yields in saline soils, and to assess tree growth and performance under an irrigated agroforestry system.

Methods

Experimental farm

This experiment was conducted at the farm of the Forestry and Gum Arabic Research Centre at Soba (Latitude 15º 30′ N; Longitude 30º 30′ E), south of Khartoum on saline soils during the period from March 2017 to November 2017. The climate of the area is semi-arid characterized by very low and erratic rainfall averaging 164 mm per annum that occurs mostly between July and September. The average annual temperature is about 30º C; the hottest months are May –June with average temperatures of 42ºC and the coldest months are December–January with an average temperature of about 10ºC. The average relative humidity is 21%, which drops to about 13% during the spill of the hottest winds of March and April and rises to 42% during the wetter period in August according to the Khartoum Meteorological Station (the year 2014).

The vegetation is composed of Acacia *seyal*, *Balanites aegyptiaca* and *Capparis decida* including naturalized *Prosopis chilensis* The terrain is flat and composed of clay soils known as Vertisols. The soil profile is markedly differentiated showing the following general features: Dark greyish brown soil, the texture is clay loam over clayey, moderate medium and fine subangular blocky structure over weak coarse medium, and fine subangular blocky structure over massive, moderately to strongly calcareous soil matrix giving an alkaline soil reaction or pH. The 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 1 and 2. The soil is slightly sticky and slightly plastic wet, with moderate medium and fine subangular blocky structure, few stones, fine ravels, and common sand grains, few $CaCO_3$ grey

nodule sand white soft aggregates, few coarse, medium, and fine roots for the soil layers [5].

Field experiment

One-year-old seedlings of *Ziziphus spina christi* (Sidr) were produced at the nursery of the Forestry and Gum Arabic Research Centre. The seedlings were planted in March 2017 under field conditions using a spacing of 4x4 m. The seedlings were watered periodically at a once-a-week interval from a permanent water supply source during the period from March to June. They were then subjected to natural rainfall during the wet season, in addition to supplemental irrigation using the permanent water source from July to November. The improved cowpea (*Vigna unguiculata*) variety known as "Ain Al Ghazal" which was released by Alobeid Agricultural Research Station was integrated as intercrops within the trees as a summer crop. The tree and crop treatments were arranged in randomized complete blocks design with three replicates. The main treatment was the tree (*Ziziphus spina christi*) component which was established at a fixed spacing of 4x4 m. The cowpea intercrop was sown on the first of August using a spacing of 50 x 25 cm and 3 seeds per hole. The intercrops were sown at two different distances of 1.0 (ZS1) and 1.5 (ZS2) meters from the trees' trunks. In addition, sole crops and sole trees were incorporated as controls. The cultural practices viz ploughing and weeding were carried out for trees and crops as necessary.

The experiment plot size was 12x8 m for each treatment and the number of trees per treatment was 12. Therefore, the total area of the experiment was 225*150 $m^{2,}$ and a total number of trees per ha was 1250 trees.

Tree and crop-measured parameters

Tree height (cm), tree collar diameter (mm), and tree crown diameter (m) were measured monthly after the well establishment of the trees in May. On the other hand, the parameters that were measured for cowpea were: straw biomass (kg/ha) and crop yield (kg/ ha).

Land Equivalent Ratio (LER)

The Land Equivalent Ratio (LER) , defined as the fractions of intercropped crops divided by sole crops, was used as a measure of agroforestry efficiency. Thus if 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 to intercropping as stated by [24].

Statistical analysis of the generated data was carried out using Genstat software. The differences between the treatment means were determined using ANOVA. LSD (Least Significant Differences at 5% level and 1% level) was used to separate differences between treatment means.

Results

Tree Growth Measurements

Height (cm)

Highly significant differences ($P<0.01$) were obtained for tree height in October only, as attributed to the effect of intercropping compared to the sole trees particularly under a wider distance (1.5 m) from tree trunks. Similarly, significant differences ($P<0.02$) were recorded in November for the wider spacing as compared with the other months (Fig. 1).

Collar diameter (mm)

Tree collar diameter gave a highly significant ($P <0.001$) effect in May and August ($P<0.003$) on both spacings than the sole trees. In June the effect was more significant ($P<0.03$) under the wide spacing and the control than in the narrow spacing. Moreover, the two spacing treatments gave significant ($P<0.05$ and $P<0.03$) effects on collar growth in July and September under the intercropping when compared with the control as indicated in Fig 2.

Crown diameter

Tree crown diameter was found significant ($P<0.03$) in September showing higher growth under the intercropping when compared with the control as depicted in Fig. 3.

Cumulative growth values *of Z.spina christi*

The average cumulative values of tree height were higher under the intercropping treatments than in the control, particularly under the wider spacing. Similarly, the average cumulative value of tree collar diameter was higher under the wider spacing, followed by the narrow spacing and the control. The average cumulative value of crown diameter was higher under the intercropping, particularly under the wider spacing followed by the narrow when compared with the control (Fig.4).

Crop yield

Cowpea straw biomass showed significant difference ($P<0.05$) concerning distances from the tree trunk. However, cowpea yield (kg/ha) did not reveal any significant differences concerning distances from tree trunks as indicated in Table 3.

Land Equivalent Ratio for cowpea intercropped with *Z. spina christi*

Land equivalent ratio was higher under the cowpea/Ziziphus agroforestry system. This agroforestry system was found more advantageous under the ZS2 for both straw and crop yield as presented in Table 4. The total LER was higher under intercropping as compared with mono-cropping.

Discussion

Z. spina christi is a multi-purpose tree species of natural existence and predominates in many parts of Sudan, especially the drier areas such as Khartoum State. The tree has different forms and characteristics and it can reach between 5-10 m in height as reported by [2,7]. The average cumulative growth in tree height for *Ziziphus spina christi*

was higher under this intercropping system on saline soils under irrigation. In this respect, Baumer [2] reported that *Ziziphus spina christi* can grow in many soil types besides being drought hardy, very resistant to heat, and can be found in desert areas with an annual rainfall of about 100 mm, only. In addition to that, the tree develops an extremely deep taproot and has extraordinary regenerative power, and can grow on clay soils where water is available and also in saline soils. The average cumulative value of tree collar diameter proved to be higher under the intercropping system which might be due to the availability of abundant water besides favorable conditions that were induced by ploughing and weeding when compared with the control treatment that was ploughed within the tree trunk and has less competition effect. In addition to that, cowpea has a tap root that was not affected by the tree's shallow roots. This in agreement with Ong e*t al* [20]who reported that in dry land, the major agroforestry problems can be manifested in competition between herbaceous and perennial crops in sharing resources. Sharing resources can be over above and below ground resources. Thus competition will be more severe in below-ground resources if tree roots are shallow as well as herbaceous crops. In order to avoid this, the approach could be to use tap roots for trees and shallow roots for crops as indicated by Nair [17]. Meanwhile, competition for above-ground resources in humid areas is more severe, such as in the case of light interception for plant photosynthesis. In this respect, Kessler and Breman [12] stated that the amount of light that is intercepted depends on tree crown, spacing, and species.

The significance of tree growth in crown width could be due to the fact that the trees are in their early stages of development. However, the increase in average cumulative growth under wider spacing could be attributed to minor competition between the trees and crops. Therefore, the competition for water was less than for other resources. Similar results were obtained by [21] who reported that under early stages of growth, the competition between crops and trees is less. In line with the above, the increase in cowpea straw biomass in the wider spacing could also relate to less competition. This is in addition to the fact that salinity was higher in deep soil layers as shown earlier in our analysis. Generally, it can be concluded that competition for below-ground resources is minor under this agroforestry system. Nevertheless, *Z.spina christi* is a drought-tolerant tree that can withstand high levels of salinity [2,19]. Other authors [11] reported that crop growth improved by the existence of shrubs which allow crops to grow larger and mature faster.

The high LER is advantageous in increasing straw growth under this agroforestry system of intercropping *Ziziphus spina christi* using wide spacing. This result in contrast with [3] who stated that under intercropping of *poplar* with *alfalfa* at different spacing, most of the dry weight production had been in narrower spacing than in the wider ones. However, the crop yield decreased under narrow spacing due to the effect of competition. This is in line with [16] who stated that some trees have an adverse impact on the associated field crops, as in the case of *Acacia nilotica, A.indica,* and *Albizia lebbeck* grown under boundaries with castor and pigeon pea. In contrast, other results obtained by [13,18,8], revealed that agroforestry, particularly intercropping, can offer an increase in productivity and economic benefits and provides more diversity in the ecological goods and services. Therefore, the present agroforestry system can be advantageous over conventional agricultural and forest production methods in the dry lands of Sudan which are subjected to land degradation and desertification

Based on the above results it is recommended to intercrop cowpea with *Ziziphus spina christi* under the saline soils of Khartoum State by sowing cowpea at a distance of 1.5 m from tree trunks. This agroforestry combination is expected to secure farmers' food and maintain fodder for their animals and thus improve their livelihoods, halting desertification besides sequestering carbon even under the saline soils of the semi-arid areas of Sudan.

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