Research Article

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Biostatistical analysis on desertification in the drylands

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Abstract
Ziziphus Spina Christi was intercropped with barley [Hordeumvulgare] under irrigation regimes in saline soils of dry lands of Sudan. That aimed to find out suitable agroforestry system to suit saline soils as well as to investigate the effect of Z. spinachristspacing on barley yield as a winter fodder crop. The experiment was laid out in terms of a completely randomized block design with 3replicates. Where the trees as the main factor spaced at 4x4mbesides barley crop that inter sown at two levels from the tree truck at 1 m [ZS1] and 1.5 m [ZS2] at two consecutive seasons in 2018 and 2019. Besides soil samples were determined in terms of pH, N, P, K, Organic Carbon at two depths 0-30 cm and 30-60cm. The trees were measured in terms of tree growth namely; tree height, tree collar and canopy diameters, and fruit yield per tree.

While barley crop was determined in terms of plant height, a number of plants, and forage yield as fresh and dry per ha per ha as well as a land equivalent ratio. The results revealed that tree growth and fruit yield did not differ in the first season of 2018. Whereas in 2019; tree height was increased by 40 cm and 38 cm when compared ZS1 and ZS2 with control. Similarly, tree collar and canopy diameters were significant under ZS1. Barley biomass dry weight was increased by 78% and 112% when comparing ZS1 with ZS2 and control respectively. Z. spinachristifruit yield was higher under ZS2 than ZS1 and control. Soil K, P, Organic carbon, and C/N were higher under intercropped plots, particularly at 0-30 cm depth. Soil salinity increased by increasing soil depths. Barley plant height was higher under control than intercropped ones in 2018.

The land equivalent ratio [LER] was advantageous particularly in 2019, it recorded 10 in ZS2 when compared with ZS1 which recorded 8. Therefore ZS2 is most suitable for intercropping barley with Z.spinachristito to maintain food security and halt desertification in dry lands.

Keywords: *Agroforestry, intercropping, Ziziphus spina christi, barley, saline soils, Land Equivalent Ratio*

Introduction

Agroforestry is a land use system that deliberately incorporates the integration of forests into agricultural lands and agricultural land into forests. Therefore, it aims to manage the natural resources in a sustained manner that provides productivity and protection means for lands for sake of human and animal benefits [1]. Thereby, some agroforestry systems or techniques would maintain and improve the existing farming systems [2-4]. In this respect, growing crops between woody perennials is widely practiced in many African and Asian countries and it was considered an old agroforestry practice. Hence, trees' characteristics, density, and spatial arrangements are the main factors in succeeding these agroforestry systems [5].

Moreover, appropriate agroforestry systems depend on the degree of competition between trees and crops on various resources. These resources are competition for above and below-ground resources. Thus they can be identified in light inception, nutrients, and water uptakes [6]. On the other hand, trees compensate soils by ameliorating their physical properties by penetrating trees' roots into deep soil layers [7]. Also, trees improve soil chemical properties by adding elements such as nitrogen fixation by leguminous trees or decomposition of tees leaves. Besides that 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 [8-12].

Barley (*Hordeumvulgare*) belongs to gramineae family. It is considered one of the food security crops. However, it comes as the fourth crop world widely after wheat, rice, and maize in terms of area size and production. Barley has multiple uses such as food for humans and fodder for animals, thus it can be mixed either as green or dry or can be incorporated with other elements. Barley is growing in winter and it tolerates salinity and considers as drought-resistant crop [13-16]. Barley can be harvested in a period of 70 days when it is grown as fodder or in 3 months in terms of grain yield.

Barley is rich in carbohydrate and protein contents and it has less fiber content [17-19].

Therefore, the introduction of this agroforestry system in terms of intercropping of *Z.spinachristi* that is characterized by the following characteristics; it is drought resistant, can tolerate salinity as well as have multiple uses such as its fruit being edible. The leaves are browsed by animals, the wood uses in furniture, and branches in fencing [20-22].

Therefore using this multi-purpose tree with promising field crops, in saline soils will increase the potentiality of these soils to be productive.Moreover, it will diversify farmers' income, maintains food security, halts desertification, and sequesters carbon. The objectives of this experiment were to find out an agroforestry model that suits saline soils of Khartoum State and to investigate the effect of tree spacing on some crop yields in saline soils.

Materials and Methods

Site Description

This experiment was conducted in Forestry and Gum Arabic Research Centre Farm in Soba, Khartoum State, Sudan [Latitude 15º 30′ N; Longitude 30º 30′ E] in Saline soils during the period of July 2018 to 2019. The soil in the site was known as Elbageer soil series, and classified as SodicHaplocombids. The parent material is Blue Nile Alluvial, the drainage is moderately well drained, moisture conditions are below 10 cm, while groundwater is very deep.

The general soil features in the experimental site are deep flat, moderately well drained, with dark brown, over very grayish brown soil color. The soil texture is clay loam, over clayey, moderate medium, and fine subangular blocky structure. The soil is of the weak coarse, medium, and fine subangular blocky structure over a massive moderately to strongly calcareous soil matrix. And soil pH is alkaline ranging between 7.6 and 8.6as indicated in Table 1 below:

The site has the following features at the different layers; it is moist; colour clay loam; friable moist; slightly sticky; slightly plastic wetat 0-30cmlayer. While it is a very dark grayish brown moist color clayey; firm moist; sticky and plastic wet at 30-60 cm. In 60-100 cm layer; it is very dark with grayish brown; moist; colour clayey; massive; few sing sand and grain; few CaCo3; white soft aggregated; few hair roots and decayed roots; strongly calcareous; pH is 8.6 at 60-100 cm. The soil texture class is clay loam according to the soil Survey Division [1993]. The soluble Cations are moderately furnished in the surface layers and increase with the soil dept. The soil is also poorly furnished in the Organic Carbon, N, and P nutrients [Tables 1 &2].

Table 1: Soil chemical properties in the experiment site in Soba in 2017

Depth	EC	$CaCO_3$	SAR	ESP	pH paste	N	O.C	C/N
cm	ds/m	%				%	%	Ratio
0-30	2.1	1.95	9.5	10.5	7.9	0.8	0.49	6
30 – 60	2.5	2.3	10	11	8.4	0.83	0.49	6
60 - 100	16.1	5.2	30	30	9.1	0.82	0.49	6

EC (Exchangeable Conductivity), N (Nitrogen Content) and O.C (Organic Carbon).

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

Depth	Soluble Cations			Soluble Anions		Excl. cal		Avai P	CEC
cm	Na	Ca	Mg	CL	HCO_3	Na	K	ppm	
0-30	13.15	9.15	1.95	10.7	1.2	11.4	0.525	2.2	35.5
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

The area is of semi-arid region with low rainfall amounts. The vegetation of the site is composed of local tree species such as Hegleg [*Balanitesaegyptiaca*], Tundub [*Capparis decidua*], and mesquite [*Prosopischilensis*].

Experimental Farm:-

The experiment was located in a protected area that was fenced with barbed wire and connected to the perennial water supply. Therefore, trees *of Ziziphusspinachristi* one year old that spaced at 4x4 m were intercropped with barley crop [*Hordeumvulgare*]. A completely randomized block design with 3 replicates was used. The barley crop was sown by broadcasting at spacing of one m [ZS1] and 1.5 metres [ZS2] apart from the trunk of the tree in two consecutive seasons in January 2018 and 2019 respectively. Control plots for both trees and crops were used accordingly. The experiment was watered once per week during the growing seasons. Routine cultural practices such as ploughing and weeding were carried out for both the crop and the trees.

The plot size was 12x8 m for each treatment and the number of trees per plot was 12 trees. Therefore, the total experiment area size was 225*150 square metres and the total trees per ha are1250 trees for *Ziziphus spina christi*.

Parameters that measured for the trees were:-

Ziziphus spinachristitrees growth parameters in terms of tree height in cm, tree collar diameter in mm, tree canopy diameter in m, and tree fruit yield per tree in grams were determined in the first season in March at age of one-year-old in 2018 and of two years old in second season of 2019.

parameter s that Measured for the Crop

Barley crop was measured in terms of plant height in cm, number of plants per ha, and crop biomass weight as fresh and air-dried weight in kg/ha for the two seasons in 2018 and 2019.

Land Equivalent Ratio [LER]

Land Equivalent Ratio [LER] in terms of crop yield and fruit yield was calculated according to Sullivan [996]. Where the sum fractions of crop yields on the intercrops relative to their mono-crops yield provide a measure of the overall effectiveness of the mixed systems. Therefore, the system is expressed in terms of LER= Xi/Xs+Yi/Ys, where Xs and Ys are the components of yield in either an intercrop where; [I] and [s] are the mono-crops system. In this respect, if the LER is more than one that means intercropping is advantageous and vice versa when is less than one [12,23,24].

Soil Analysis

Soil samples were taken by Auger from the following places; under the intercropped Ziziphus *Spina christi* trees canopy, sole *Z.spinachristi* trees canopy, and in the open areas at two depths; 0-30 cm and 30-60 cm to determine soil fertility in terms of Nitrogen, Phosphorus, Potassium and Organic Carbon as well as pH at the end of the second season in 2020. The samples were taken to the Soil and Water Centre of Agricultural Research Corporation in Wad Medani and analyzed there.

Statistical Analysis

The generated data were analyzed by using GENSTAT Software. The differences between the treatment means of the ANOVA tables were determined by using LSD [Least Significant Differences at 5% level].

Results Tree Growth Measurement

The tree measurements for *Z.spinachristitree* in terms of tree height, tree collar diameter, and tree canopy diameter did not differ significantly with respect to distance from the tree trunk when intercropped with barley crop or as sole trees in the first season 2018 as indicated in table3.

While for *Z.spinachristi* fruit yield it was higher under the first treatment [ZS1] than in ZS2 and the control as indicated in table 3.

Meanwhile, in the second season 2019, the tree height of Z.spinachristiwas found to be higher in ZS1 than in ZS2 and control. It has amounted to 2 cm and 38 cm increase when compared with the two treatments respectively. Whereas ZS2 increased by 38 cm when compared with the control as shown in table 3.

Z.spinachristi tree collar showed highly significant differences at [P<0.001] that indicated in an increase of ZS1 and ZS2 by 8.4 mm and 7.4 mm when compared with the control respectively as indicated in table 3.

While *Z.spinachristitree* canopy diameter showed highly significant differences at [P<0.01 level].
However, it was higher at ZS1 which amounted to 1.6 m and 3m increase when compared with ZS2 and control respectively as indicated in table 3.

While *Z.spinachristi* fruit yield; was higher under intercropping than in control plots. Therefore, it was higher under ZS2 which showed 30% increase when compared with ZS1. And it was increased by 546% when compared ZS2 with control. And 394% increase when compared ZS1 with control as indicated din table 3.

Table 3: Tree height cm, tree collar diameter mm, tree canopy diameter m, and tree fruit yield in gram under the agroforestry system in the first and second seasons 2018 and 2019.

Treatments	Tree height in cm	Tree collar diameter in mm	Tree canopy diameter in m	Tree fruit yield g/tree
Season 2018				
ZS1	181.6±17.03a	16.2±3.69a	9.00±2.20a	330
ZS2	207.8±17.03a	19.3±3.69a	4.73±2.20a	250
Z	127.6±17.03a	10.8±3.69a	3.03±2.20a	226.7
Sig. level	Ns	ns	ns	
Pro	0.16	0.13	0.24	
CV%	12	35.0	48	
LSD	37.95	8.22	4.91	
Season 2019				
ZS1	240.6±14.87a	33.83±2.95ab	6.65±0.633a	1072.46
ZS2	238.3±14.87a	32.17±2.95ab	5.02±0.633a	1403.08
Z	200.1±14.87ab	24.78±2.95a	3.66±0.633c	217.2
Sig.level	*	**	**	
Pro	0.05	0.003	0.001	
CV%	10.7	14	11.6	
LSD	46.86	6.86	1.411	

Means followed by the same letters are not significantly different at 5% or 1% level. ns=not significant. Key Legend: Z= *Ziziphus spina christi*, S1= crop cultivated one meter from tree trunk.S2=crop cultivated 1.5 meters from tree trunk.

Barley crop parameters

In the first season 2018 barley plant height was highly significant at [1% level], thus it was higher under sole crop when compared with intercropped treatments, which increased by 394% and 278% when compared control with ZS1 and ZS2 respectively as indicated in table 4. Similarlybarley biomass dry weight was significant at [P< 0.05 level] particularly under ZS1 when compared with ZS2 and Control. However, ZS1 increased by 78% and 112% when compared with ZS2 and control respectively. And it amounted to 55% when compared ZS2 with control as indicated in table 4. Whereas no significant differences were recorded for the number of plants per ha and biomass fresh weight with respect to tree species and spacing from the tree trunk as indicated in table 4.

In the second season 2019 no significant differences were recorded for the tree species with respect to distance from the tree trunks for the above-mentioned parameters in terms of plant height, number of plants per ha, and fresh and dry biomass weights per ha as indicated in table 4.

Table 4: Barley plant height cm, number of plant/ha, biomass fresh yield kg/ha, and biomass dry yield kg/ha in the first and second seasons 2018 and 2019.

Treatments	Plant height kg/hakg/ha	No. of plant/ ha	Biomass fresh	Biomass dry yield cm yield
Season 2018				
ZS1	11.7±5.05a	1493867±1160965.4a	12397±4105.2a	5280±781.1a
ZS2	13.7±5.05a	289333±1160965.4a	12332±4105.2a	4585±781.1ab
Control	51.8±5.05b	2202800±1160965.4a	7270±4105.2a	2959±781.1c
Sig. level	**	ns	ns	*
Pro	0.001	0.456	0.098	0.055
CV%	30.4	54.7	20	20.2
LSD	11.65	2677189.5	4105.2	1801.3
Season 2019				
ZS1	40.2±3.48a	3142667±766254.8a	2809±598.6a	442±277.2a
ZS2	42.9±3.48a	2240000±766254.8a	2924±598.6a	1509±277.2a
Control	36.7±3.48a	3832000±766254.8a	1840±598.6a	1611±277.2a
Sig. level	ns	ns	ns	ns
Pro	0.782	0.503	0.481	0.783
CV%	15.0	39.6	36.8	29.3
LSD	11.35	2498895.3	1952.2	904.1

Means followed by the same letters are not significantly different at 5% or 1% level.

**Significant at P ≤ 5% and ** significant at 1% level. ns=not significant.* Key Legend: Z= *Ziziphus spina christi*,S1= crop cultivated one meter from tree trunk.S2=crop cultivated 1.5 meter from tree trunk.

Land Equivalent Ratio [LER]

In the first season 2018, the land equivalent ratio was advantageous for *Z.spinachristi* with barley crop regardless of distance from the tree trunk. Thus it recorded a higher value in ZS1 than ZS2 as indicated in table 5. While in the second season 2019, LERwas more advantageous under ZS2 than ZS1 which amounted to 2.2 increases as indicated in Table 5.

Table 5: Land equivalent ratio for intercropping of barley crop with *Ziziphus spina christi* in the first and second seasons 2018 and 2019.

Treatment	Intercropped barley fresh yield kg/ha	Intercropped trees fruit yield kg/ha	LER
Season 2018			
ZS1	12397	412.5	3.3
ZS2	12332	312.5	3.1
Sole barley	7270		
Sole *Z. spina christi*		226.7	
Season 2019			
ZS1	2809	1375	7.86
ZS2	2924	1750	9.65
Sole barley	1840		
Sole *Z.spinachristi*		217.2	

Key Legend: Z= *Ziziphus spina christi*, S1= crop cultivated one metre from tree trunk.S2=crop cultivated 1.5 metre from tree trunk. **Soil Analysis**

Z.spinachristiplots or sole trees and open areas in terms of soil depths namely; 0-30 cm and 3060cm. But for P, K, OC and C/N there were differences between intercropped plots at 0-30 cm when compared with the other depths. Thus P, K, OC, and C/N were been higher under 0-30 cm depth than in the other depth as indicated in table 6.

Table 6: Soil fertility analysis for *Ziziphus spina christiexperiment* in 2020 in Soba.

Treatments	Soil depths in cm	Soil pH	N%	Pppm	K	OC%	C/N
ZS1	0-30	8.0	0.08	4.93	0.53	0.78	10.3
ZS2	30-60	8.1	0.08	2.2	0.47	0.36	7.3
ZC1	0-30	8.1	0.07	2.47	0.42	0.44	6.3
ZC2	30-60	8.1	0.08	3.2	0.47	0.53	4.7
C1	0-30	8.1	0.08	2.62	0.45	0.44	6.7
C2	30-60	8.1	0.07	2.76	0.45	0.47	4.0

ZS1=intercropped *Z.spina christi* trees plots, ZC1 =Sole *Z.spina christi* trees, C1=open areas.OC=Organic carbon.

Discussion

In this study, tree measurement parameters in terms of tree height, tree collar diameter, and tree canopy diameter did not differ in the early stage when intercropped with barley crop due to minor competition between trees with the crop at this level. Similar results were obtained by when working in Acacia Senegal intercropped with field crops in Blue Nile of Sudan. While in the second season 2019, there were significant differences between tree measurement parameters, in terms of tree height, hence tree height was higher under intercropping treatments than in the control ones for the *Ziziphus spina christitrees* [24].

That is probably due to consistent watering under intercropping plots than in the sole ones. In this respect, under intercropping plots also the site was well plowed by hoes and it became more favorable for tree roots to penetrate deeply into the soil layers and leach soil salinity as well. While under sole tree plots, the areas around tree trunks were hoed and watered only. Whereas the marked variation for *Ziziphusspinachristitree* collar diameter might be probably due to favorable site conditions under intercropping as mentioned above as a result of consistent watering of the site besides the tree having tap root system, similarly for the tree canopy diameter.

Meanwhile, reported that agricultural management practices can benefit the growth rate of trees under clay soil. However, this site has more salinity with increasing soil depths, but with consistent watering and good cultural practices such as ploughing and weeding, salinity has been reduced by going upward by leaching. Furthermore, the competition for below-ground resources should be minor under this agroforestry system due to consistent watering. Nonetheless, the tree is drought resistant and can tolerate salinity as stated by [1,25,26].

Barley crop, it is drought resistant and can grow under short water resources and tolerates salinity as reported by [16,18,19]. Variation in plant height between treatments was due to competition for light; thus light interception effect under intercropping is more severe and adversely affected plant growth as reported by [27-29]. The significance of barley biomass dry weight in 2018; might be due to favourable site conditions for barley under the intercropping than in the control plots.

In this respect, the soil fertility in terms of K, P, Organic carbon, and C/N were higher under intercropped plots particularly under0-30cm soil layer which indicated the improvement of soil fertility under this layer as shown in table 9. This is in line with who reported that Organic Matter was deposited in the upper soil profile when compared with lower soil depths due to the high concentration of biological activities as a result of organic residues. Similarly, reported that Organic Carbon and Total Nitrogen content gradually decreased with soil depths. In fact, this site was considered as fallow land before and it consisted of small bushes and low rainfall amount and vegetation cover [30,31].

However, other studies revealed under such conditions soil chemical properties varied with respect to soil depths. In alignment with this reported that under pH ranging between 4-5Total Nitrogen and Organic Carbon were varied due to soil layers. However, salinity is not a determinant factor under this agroforestry system, since salinity increases with increasing soil depths. And it has reduced during the study as shown in table 9. This on contrast with table one that had showed soil pH was higher under the soil profile excavation level. Furthermore, barley has a shallow roots system that minimized interface with intercropped trees that have a deep rooting system such as Z.spinachristi. In Northern Sudan at the Merowe site, the barley crop as fodder crop yield was estimated by 5 tons per ha as stated by [31,18]. Under Gazeira environment barley crop yielded 3.7 tons per ha as reported by reported that barley crop needs low water quantity but cool temperature to yield high dry matter [32,33].

Land equivalent ratio (LER) was higher under this agroforestry system which indicates that intercropping is advantageous. That was obviously observed in the second season, where trees were becoming vigorous at maturity in their actual characteristics and phonology. Therefore, LER proportion was been higher under intercropped trees than intercropped crops; thus Z.spinachristi tree fruit was higher under intercropping than in sole trees. Therefore, intercropping is good to obtain varied crops either herbaceous crops or woody perennials, so the fruit trees were higher under intercropping than in sole trees. Similarly, reported that LER was been more advantageous in intercropping Acacia senegal with field crops such as sesame, sorghum, and millet due to different proportions of crop and gum yield values [12].

It can be concluded that Z.spinachristitree growth besides tree fruit yield was higher under intercropping. Barley crop was higher under intercropping, particularly under Z.spinachristi wider spacing ZS2 [1.5 m]. Similarly, the land equivalent ratio was higher under this agroforestry system with in wider spacing [ZS2]. Soil salinity increased with soil depths and soil fertility in terms of P, K, Organic Carbon, and C/N were higher under intercropped plots at 0-30 cm depth. Therefore, farmers can provide fodder from barley to maintain their animals during winter season besides that barley can be substitutedwith other fodder crops that require more water quantities such as Bersim [Medicago sativa] as reported by. Moreover, with little water source and effort farmers can get fodder crops of highly nutritive value from barley crops. The farmers also can get fruit yield from Ziziphus spina christitree [Nabak] which is well known in the local market and used as edible fruit. In addition to other uses of the tree such as its wood in making some domestic tools like handles furniture and charcoal. And the leaves that are used as fodder for animal feed and in local medication. Moreover, the tree has other functions such as halting desertification and in sequestering Carbon in dry lands and poor marginal soils lands [22,34].

Conflict of Interest

We have no conflict of interests to disclose and the manuscript has been read and approved by all named authors.

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