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Research paper

Assessment of Chick pea (*Cicer arietinum L.*) Productivity and its Cost Benefit Ratio under *Acacia ampliceps* Shelterbelt System in River Nile State (Sudan)

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Field experiments were conducted at Elmukabrab scheme which lies between latitudes 17º26' and 17º35'N and longitudes 33º57' and 34º08'E, about 10 km south east of Ed Damer town in River Nile State, to evaluate the effects of heavy pruned *Acacia ampliceps* shelterbelts grown in rows of five-meter-wide between hedge rows and three meter spaces between trees, on growth and yield of chickpea with an additional economic evaluation analysis of shelterbelt trees and crop yield production. The trials were established under field condition, semi-desert climatic zone during two consecutive winter seasons 2012/13 and 2013/14. Soil was of low nitrogen and organic matter. Treatments consisted of chickpea plots under *Acacia ampliceps* shelterbelts, heavily pruned with light intensity of about 60 to 70% compared to control (light intensity 100%) were arranged in a randomized complete block design with four replicates the plot size was 6×5 m. Heavy pruning was done by cutting all branches at 3 to 3.5 m above ground level of the main stem and one third of the tree canopy to increase incoming radiation which is measured by solar meter in the two different seasons compared to the control. Chick pea grain yield under heavy pruned shelterbelt was significantly increased by 15% and 13% compared to the control in first and second seasons, respectively. Economic analysis showed that the net profit of chickpea under heavy pruned shelterbelt trees was higher in the two seasons compared to the control, these were (2569 and 3308 SDG), while the control were (1610, 2190 SDG) in first and second seasons, respectively. Cost benefit ratio of the shelterbelt trees and chickpea grown under shelterbelt system greater in second season compared to the first.

Keywords: *Acacia ampliceps*, cost benefit, pruning, radiation, solar meter

تقييم الإنتاجية لمحصول الحمص والمنفعة مقابل التكلفة تحت نظام زراعة ممرات الأحزمة الشجرية المكونة من أشجار الأمبلسيبس بولاية نهر النيل ـ السودان

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المستخلص

أجريت هذه الدراسة بمشروع المكابراب الزراعي بولاية نهر النيل على خطى طول وعرض (26 17- 35 17 ش و 57 33 – 08 34 ق)، تقع هذه المنطقة حوالى 10 كيلومتر جنوب شرق مدينة الدامر التي تتميز بمناخ شبه صحراوي وتربة منخفضة النايتروجين والمادة العضوية في موسمي 13/2012 و14/2013 بهدف: تقييم إنتاجية محصول الحمص تحت نظام زراعة ممرات الأحزمة الشجرية المكونة من أشجار الأمبلسيبس بعد تقليمها (تقليم الأفرع الجانبية على ارتفاع 3.5 من سطح الأرض وثلث تاج الأشجار بحيث أصبح الإشعاع تحت ظل أشجار الحزام حوالى 60-70 % تقريباً مقارنة بالشاهد (إشعاع 100%) . تم تقييم المنفعة مقابل التكلفة لنمو وإنتاجية نظام وزراعة ممرات الحزام الشجري بمحصول الحمص والأشجار المكونة له مقارنة بالشاهد. أوضحت النتائج ازدياد إنتاجية محصول الحمص داخل ممرات الحزام الشجري معنوياً في الموسمين مقارنة بالشاهد حيث كانت الزيادة بنسبة 15 و13% في الموسم الأول والثاني على التوالي. كذلك أظهرت نتائج التحليل الاقتصادي أن زراعة محصول الحمص في ممرات الأحزمة الشجرية المكونة من أشجار الأمبلسيبس بعد تقليمها حققت أعلى ربحية (2569 و3308 جنيهاً) مقارنة بالشاهد (1610 و2190 جنيهاً) في الموسم الأول والثاني على التوالي. كذلك وجد أن معدل نسبة الفائدة لإنتاج أشجار الحزام الشجري والنظام ككل > 1 في الموسم الثاني.

كلمات مفتاحية: أمبلسيبس، تقليم، التكلفة مقابل الفائدة، إشعاع، سولار ميتر.

Introduction

River Nile State occupies about 124000 km^2, the arable land is about 88772 hectares. The total agricultural land is about 56875 hectares. Estimate of the amount actually under cultivation is about 28655 hectares (according to the Ministry of Agriculture, Irrigation and Forests Annual Report 2012). The combination of the long-term climatic changes and impacts breed incidence of extreme weather events likely to have adverse impacts on the agricultural production systems in dry land of northern Sudan (Motasim *et al.*, 2009).

Desertification in Northern Sudan is a very serious problem threatening the agricultural land and the existence of people who depend on agriculture for their livelihood. Sand encroachment is the most important element that directly affects soil by causing strong erosion hazards and endangers all valuable agricultural land resulting in a continual decline in the area of cultivated crops in northern Sudan. Shapo and Adam (2007) mentioned that semi-desert zone where the prevailing harsh climatic conditions (high solar radiation, and temperature, low rainfall and relative humidity), particularly during the summer season, causing reduced cropping during this period, this situation necessitates the development of intensive plantation of woody trees, which could provide microclimatic conditions that suit crop production as well as the farmers can benefit from wood production. One of the main effects of forest, shelterbelts and agroforestry on microclimate is on solar radiation, since the sun's rays bring not only light but also heat (Shapo *et* *al.*,2003). Agroforestry systems such as intercropping offer substantial scale mentality of water use since most of the root system of woody trees is much deeper than those of agricultural crops, so the crops intensively utilize water from shallow depths in the soil profile and the trees have the potential to extract water from deeper soil layers (Narian *et al*., 1998).

The chickpea (*Cicer arietinum L*.) is a self-pollinating diploid annual legume of the family Fabaceae, subfamily Faboideae, with 2x=2n=16 chromosomes (Tekeogluet *et al*., 2000). Chickpea is grown on flat heavy clay soil; it is grown in dark brown zones fine-textured black soil with pH 6.0-9.0. In Sudan, area production and productivity were 8000 ha, 7000 tons/ha respectively, which represent 0.4% from the total area of irrigation system (2,000,000 ha) and represent 0.8% of the world production (FAO, 2007). Recently, Sudan was ranked no 23 among top agricultural producing countries in the world with a share of only 0.1%. Moreover, Sudan production area not increased during 2007-2016 but the productivity has risen rapidly to 12000 tons and 1.7 ton/ha (FAO 2019). The chickpea crop was introduced and successfully grown in Hawata and Jebel Maraa areas (Faki *et al*., 1992). It is now grown in the River Nile State due to its relatively long and cool winter season. Recently the crop is also grown in huge areas at Gezira and New Halfa schemes.

A cost benefit analysis is done to determine how well, or how poorly, a planned action will turn out. Although a cost benefit analysis can be used for almost anything, it is most commonly done on financial questions.

This study aims at evaluating effects of heavy pruned *Acacia ampliceps* shelterbelts grown in rows of five-meter wide between hedge rows and three meter spaces between trees, on growth and yield of chickpea and its economic outcome.

Materials and methods

Site study

The experiment was carried out during two consecutive cropping seasons of 2012/13 and 2013/14 in River Nile State at Mukabrab Irrigated scheme. Experimental site lies in semi-desert climatic zone between latitudes 17º26 and 17º35 N and longitudes 33º57 and 34º08 E; about 10 km south east of Ed Damer town. Based on soil analyses in the laboratory of soil and water research department at Hudieba Research Station (HRS), soil experimental site is non-saline and non-sodic with alkaline soil reaction, low in both organic carbon (0.046%) and nitrogen content (116 ppm). With $CaCO_3$ of 8.3, pH (8.2) and sol. phosphorus (0.83 ppm). Soil in shelterbelt is richer in total nitrogen, phosphorus and organic carbon compared to the mono-cropping.

Experiment components

Acacia ampliceps shelterbelt

Acacia ampliceps exotic tree released by the Agricultural Research Corporation (ARC), was used as shelterbelts in River Nile State at Mukabrab irrigation scheme in agroforestry research programme (2006). Seedlings were raised at Gezira Research Station (GRS) nursery, three-month-old seedlings (35 – 40 cm length) were transplanted in 2006. The seedlings were grown at 3 meter in-row spacing and 5 meter inters rows. Each hedgerow was one km long and arranged in an east-west direction. The shelterbelt was composed of four rows.

Crops and varieties

The study investigated one of the most important winter legume crops in the northern region of Sudan especially in River Nile State namely, chickpea. The variety used: "Jebel Marra".

Experimental layout and design

The crop was grown under heavily pruned shelterbelt in two seasons. Light intensity under the heavily pruned shelterbelt was about 60 – 70 %. Pruning was done by cutting all branches from 3 – 3.5 m of the main stem beside one third of the canopy of the tree to increase incoming radiation (measured by solar meter). The experiment was laid in randomize complete block design (RCBD) with four replicates.

Treatments

In 2013 and 2014 seasons, chickpea was grown under heavy pruned *Acacia ampliceps* shelterbelt trees, and open field (control). The plot size was 6×5 m. The control treatments were planted on the north side of shelterbelt plots to avoid both shading and sheltering effects.

Crop management and practices

Land under shelterbelt and control plots were ploughed, harrowed and levelled. Chickpea was planted on 22th November in lines on flat (60 cm apart). Seed rate of 2-3 seeds per hole, spacing 10cm between holes a density of about 166667 plants/ha, 17 plants m^2. Manual weed control was practiced wherever needed, irrigation interval ranged between 8-10 days. Nitrogen fertilizer at the rate of 43 kg N/ha was broadcasted after second irrigation. Net harvested area was 30 m^2.

Crop parameters

Chickpea yield and yield components were assessed at the end of the seasons as follows: weight of hundred (100) seeds (g) plant height (cm), number of seeds in five plants, number of pods in five plants, weight of seeds in five plants and biomass (ton/ha).

Woody trees of shelterbelt data

For the woody trees, and from the four different rows (replications), measurements were done for tree height/meter, diameter at breast height (DBH) and diameter at the base of the trees (at 10 cm above the ground level) in (cm). Diameters were measured using a caliper. In addition, fresh and air dry weight of branches, twigs and leaves in kg were done in the two pruning treatments. Branches with diameters less than 5 cm were used as fire wood and branches more than 5cm were burnt by traditional method to produce charcoal in first and second seasons.

Economic analyses

From this study, economic analysis used partial method, benefits were itemized by adding all positive factors then all negative items and cost were identified and quantified. The difference between the two indicates whether the planned action was advisable or not. Cost-Benefit Analysis (CBA) estimates and sums up of the equal money value of the benefits and costs to community of the projects to establish whether they are valuable were assessed.

Revenue = Quantity * price

Net profit = Revenue – Total cost of items

Economic dry leaves as forage crop production values calculated between chickpea and *Acacia ampliceps* dry leaves yield produce unit and crude protein ratio as follows;

$$P = \frac{(Ya \times CP2)P1}{CP1}$$

Where; (p) is price of *Acacia ampliceps* as forge crop product unit, (Ya) is yield of *Acacia ampliceps* as forge crop, (CP2) is crude protein of *Acacia ampliceps* dry leaves, (P1) is price of alfalfa product unit, (CP1) is crude protein of chickpea.

Cost benefit ratio = R/Tc

R = Revenue (gross benefit), Tc = Total cost.

Results

Effect of heavy pruned shelterbelt trees on chickpea yield

In both seasons, chickpea grain yield, weight of hundred (100) seeds, plant height, number and weight of seeds in five plants, and biomass were significantly higher under *Acacia ampliceps* shelterbelt compared to control. *Acacia ampliceps* shelterbelt increased chickpea grain yield by 15% and 13% in the first and second seasons over control, respectively (Table1).

Yield and yield components of chickpea crop in both seasons under *Acacia ampliceps* shelterbelt manifested significantly higher results (in mean of the two seasons) over the control treatment, as yield 926 compared to 812 kg/ha, hundred (100) seeds weight of 13.6 compared to 12.2 g, plant height of 54 compared to 46 cm, number of seeds in five plant of 124 compared to 108, weight of seeds in five plants of 16 compared to 12 g and biomass of 2.3 compared to 1.9 ton/ha, respectively, however, differences on number of pods in five plants was not significant (Table 2).

Economic evaluation of system composes

In both seasons, the net profit for chickpea grown under heavy pruned *Acacia ampliceps* shelterbelt was better than the control. Fixed cost of *Acacia ampliceps* shelterbelt trees establishment was 18328 SDG/ha (Table 3 and 4).

Acacia ampliceps shelterbelt trees product of dry leaves as the forage animal feed production, and wood production were better in first season compared to the second season. The cost benefit ratio of shelterbelt and chickpea under shelterbelt system were greater in the second season compared to the first season (Table 5).

Discussion

The results indicated that chickpea crop performed better under *Acacia ampliceps* shelterbelt with 60 – 65% transmitted radiation compared to the control. The competition for light was the major factor contributing to plant photosynthesis. The modified microclimate might lead to an increase in the chickpea growth and yield components as it needs cooler temperatures. The most benefit of shelterbelts is protecting adjacent soil and crops from injury of the erosive wind. However, farmers are often averse to implement this conservation. The main reason is that shelterbelts occupy valuable land of production and compete for moisture and nutrients with crops. Scientific research in other parts of temperate regions shows that improved yields adjacent to shelterbelts can help to compensate loss in production (Yuhai *et al.*, 2012). Also, Adlan *et al.* (2020)

mentioned that wheat crop under *Acacia amplceps* shelterbelt increased by 51 and 42% over control at 17th November (optimum sowing date) and after that by month at 17th December, respectively. On the other hand, Sauer *et al*., (2007) reported that a shelterbelt field windbreak is an agroforestry practice that consists of one or more rows of trees planted across crop fields or grazing lands to reduce wind speed and enhance the local microclimate for crop and animal production. Shelterbelts are most common in semiarid areas where they also protect the soil from wind erosion. Agroforestry provides an opportunity for farmers to diversify their farms and thus increase sustainability and resilience to shocks by reducing the consequences of crop-failure. Trees also provide a number of ecosystem services such as erosion control, flood control and pest control, all important for resilience to climate change (Verchot *et al*., 2007; Mbow *et al*., 2014). Agroforestry can thus buffer climate extremes, expected to become more common in the future (Mbow *et al*., 2014).

In both seasons economic evaluation analysis indicated that the net profit of chickpea crop under heavy pruning *Acacia ampliceps* shelterbelt trees was better compared to the control. But the chickpea crop under heavily pruned *Acacia ampliceps* shelterbelt trees at the system net profit was better in the second season. Agroforestry system not only offer environmental services but they also offer many products such as food, timber, fodder, medicine, and fuel wood. Selling other agroforestry products such as timber, fire wood and fruit, can increase and diversify income and food sources (Waldron *et al*., 2017; Mbow *et al*., 2014; Sharma *et al*., 2016). Also, Tougiani *et al*. (2008) studied how food security and income generation in rural communities changed after agroforestry practices were implemented in Niger. They found that trees on the farms had increased the domestic consumption and that the sale of tree products, especially fuel wood, was an important contributor to farmer income.

Conclusions

Acacia ampliceps shelterbelt has seemed to create a good and conducive environment to increase yields and crops production. In both seasons the net profit of chickpea grain yield grown under *Acacia ampliceps* shelterbelt was higher compared with that grown under the control. The revenue from heavy pruning of *ampliceps* shelterbelt trees production can cover the cost of shelterbelt management, therefore, the cost benefit of chick pea grain production grown under heavy pruned *acacia ampliceps* shelterbelt as the system showed in the second season was greater than one.

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Table (1). Yield and yield components of chickpea under *acacia ampliceps* shelterbelt system and control plots in seasons 2012/13 and 2013/14.

Season 2012/13								
Treatment	Yield (kg/ha)	Yield % as control	Weight of 100 seed (g)	Plant height (cm)	Number of seed in five Plant	Number of pods in five plants	Weight of seed in five plants (g)	Biomass (ton/ha)
Shelterbelt	874	15	13.4	53	123	123	16	2.2
Control	761	-	12.1	45	106	125	12	1.7
Sig.L	*		*	*	*	NS	*	*
S.E±	19		0.1	1.4	3	3	0.5	0.1
C.V%	5		2	5	4	3	6	6
Season 2013/ 14								
Shelterbelt	978	13	13.7	54	125	128	16.7	2.4
Control	863	-	12.2	47	110	130	12.3	2
Sig.L	*		*	*	*	NS	*	*
S.E±	20		0.1	1	1.2	2	0.6	0.04
C.V%	5		2	3	2	3	7	4

Table (2). Combine analysis of yield and yield components of chick pea under *Acacia ampliceps* shelterbelt and control plots in two seasons (2012/13 and 2013/14).

Season	**2012/13**		**2013/14**		**Mean**		**Sig.L**	**S.E±**	**C.V %**
Treatments	**Shelterbelt**	**Control**	**Shelterbelt**	**Control**	**Shelterbelt**	**Control**			
Yield (kg/ha)	874	761	978	863	926	812	**	15	5
Weight of 100 seed (g)	13.4	12.1	13.7	12.2	13.6	12.2	**	0.1	2
Plant height (cm)	53	45	54	47	54	46	**	1	4
Number of seed in five Plants	123	106	125	110	124	108	**	1.3	3
Number of bods in five plants	123	125	126	127	125	126	NS	1.3	3
Weight of seed in five plants (g)	16	12	17	12	16	12	**	0.4	7
Biomass (ton/ha)	2.2	1.7	2.4	2	2.3	1.9	**	0.04	5

Table (3). Chickpea items cost and net profit (SDG/ha) under *Acacia ampliceps* shelterbelt trees and control in two seasons.

Season	**Season 2012/13**		**Season 2013/14**	
Items	**Shelterbelt**	**Control**	**Shelterbelt**	**Control**
Land preparation	480	480	624	624
Seed cost	336	336	428	428
Seed broadcasting	667	667	1000	1000
Fertilizer	432	432	523	523
Hand weeding	333	333	500	500
Water irrigation	450	450	480	480
Hand harvest	562	562	1000	1000
Harvest	333	333	667	667
Empty sacks/bags	45	40	100	90
Transportation	45	38	70	63
Total cost	**3683**	**3670**	**5392**	**5375**
Crop seeds product revenue	5244	4566	7335	6473
Revenue of crop forage production	1008	714	1365	1092
Revenue of crop seeds and forage production	**6252**	**5280**	**8700**	**7565**
Net profit of chick pea productivity	**2569**	**1610**	**3308**	**2190**

Table (4). Cost items of *Acacia ampliceps* shelterbelt establishment before growing chickpea crop (SDG/ha).

Items	Cost (SDG/ha)
Seedling	1568
Transportation of seedlings	392
Land preparation	480
Labour	720
Water man	7968
Irrigation worker	7200
Total cost	**18328**

Table (5). Cost benefit, revenue and net profit production economic analysis of chickpea under heavy pruned *Acacia ampliceps* shelterbelt system.

Cost benefit, revenue and net profit production	Season 2012/13	Season 2013/14
Dry leaves as forge production (ton/ha)	3.6	2.2
wood production (m^3 /tree)	0.08	0.06
Wood production (m^3/ha)	61	45
Number of sack/ha	146	108
Cost benefit worker of dry leaves as forge (SDG/ha)	857	733
Cost benefit of cutting worker fire wood production (SDG/ha)	2205	2695
Cost benefit of dry leaves as forge and wood (SDG/ha)	**3062**	**3428**
Selling production of dry leaves as forge (SDG/ha)	7380	4510
Selling production of wood m^3 (SDG/ha)	7320	6750
Revenue of dry leaves as forage animal feed and fire wood (SDG/ha)	**14700**	**11260**
Net profit of dry leaves as forge production (SDG/ha)	6523	3777
Net profit of wood production (SDG/ha)	5115	4055
Net profit of dry leaves as forge with wood production (SDG)	**11638**	**7832**
Total cost of shelterbelt establishment, and dry leaves as forage crop and wood product (SDG/ha)	21390	-6690
Net profit *Acacia ampliceps* shelterbelt trees (SDG/ha)	-6690	1142
Net profit of chickpea under *Acacia ampliceps* shelterbelt system (SDG/ha)	**-4121**	**4450**
Cost benefit ratio of *Acacia ampliceps* shelterbelt trees	**0.7**	**1.7**
Cost benefit ratio of chickpea under*Acacia ampliceps* shelterbelt sytem	**0.8**	**1.7**