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Production function and profitability of fennel crop (*Foeniculum vulgare*) in Dongola Locality, Sudan.

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Abstract
The objective of this study was to analyze the economics of fennel production in Dongola Locality, Sudan, through examining the socio-economic characteristics of fennel-producers, investigating fennel costs, returns and profits and derive fennel's production function. A multi-stage random sampling technique was used to collect data from 120 respondents by means of questionnaire during 2009/10 season. Descriptive statistics, gross margin and regression analysis techniques were used to reach the stated objectives. Results revealed that; fennel producers in the state used their resources improperly. All inputs used were significantly less than the proper quantities, even though, farmers gained encouraging profits (1300 US$/ha). The regression analysis exposed that, irrigation numbers; seed rate, finance and pesticide were the major explanatory variables affected fennel production. There is a great potential for improving farmers productivity/profitability if certain measures were carefully adopted. These measures revolve around improving the technical knowhow of the farmers (strengthening of extension services), their access to microfinance and reducing farmer's costs through adoption of technical crop package and removing/reducing taxes.

Keywords: *Socio-economic characteristics, costs of production, fennel productivity*

Introduction
Fennel (*Foenicum vulgare*) is a worldwide crop produced in many countries of the world. Countries with largest volume of fennel output include India, Mexico, China, Iran, Bulgaria, Syria, and Morocco with an average of 110, 50, 40, 30, 28, 27.7, 23 and 22 thousand tons, respectively (FAO, 2015). The crop is highly demanded, both in Sudan and the world, for cooking, medicinal purposes and cleaning because it is very rich source of vitamin C, foliate, fiber and potassium. It is also characterized by high market value and long preservation period.

Fennel, in Sudan, is mainly produced in the Northern State, consumed in Khartoum State and sold abroad to the Gulf States (FEWS, 2011). Northern State of Sudan occupies an area of about 34.9 million hectares, lies in the arid and semi-arid zone and characterized by two distinct seasons: Summer and Winter. The State is administratively divided into

seven localities: Halfa, Al-porgieg, Al-golid, Dongola, Al-Debba and Marawi, each with a number of administrative units. The total cultivated area in the State is estimated at 200 thousands hectare, about 75% of which is cultivated in winter. Wheat and faba bean are the main winter crops produced in the State. They occupied the largest winter cultivated area: 43% and 31% respectively. Fennel is mainly cultivated in Dongola locality, which produced the bulk (87.47%) of fennel and constituted about 67% of the total spices cultivated area in the Northern State (MAAI, 2016). On the other hand, although fennel cultivation is not covered large area compared with the two mentioned crops, yet it is one of the main sources of income. The area under the crop is fluctuated around 2243 ha/ season, with poor yield in majority (Table 1). (MAAI,2016)

Table 1: Fennel total area, total production and yield in Northern State

Years	Area (Ha)	Production (Tons)	Yield (Tons/ha)
2006	2185	2311	1.06
2007	2764	2924	1.06
2008	1887	2195	1.16
2009	2839	2282	0.80
2010	2479	2360	0.95
2011	2503	2377	0.95
2012	1335	1268	0.95
2013	1646	3127	1.90
2014	2221	3132	1.41
2015	2340	2106	0.90
2016	2475	2351	0.95

Northern state is characterized by good and suitable weather conditions, vast fertile land, and abundant water for irrigation and skilled labor for its production (Elfeil, 1993). The average yield in the research station, for the same period, was 2.5 tons/ha (Fagiri, Elrasheed: Director Agricultural Research Corporation Hudaibia, Norhern Sudan, personal interview (2013)). Also (Abdallah, 2005) and (Elfeil, 1993) attributed the deteriorating yield to inefficient resources allocation and low farmer's income. They attributed the farmer's mismanagement of resources to many factors the most important of them are: high inputs cost especially fuel for irrigation, unavailability of inputs at the right time, and land fragmentation.

Analysis of fennel production in Dongola locality is very limited. The main goal of this study was to evaluate the economics of fennel production for the underground-water irrigated schemes (since it represented by the majority of the surveyed farms) in Dongola locality Northern State of Sudan. This main goal studying was fulfilled through the socio-economic characteristics of the farmers; investigating fennel costs, returns and profits and deriving fennel's production function.

Materials and Methods

The study depended on both primary and secondary data, although primary data was the main source. Primary data, on technical and economic aspects of fennel production for 2009/2010 winter season, was collected by using a questionnaire constructed purposely for this study. A multi-stage random sampling technique was used to collect data from 120 respondents in Dongola locality, representing about 10% of the total fennel producers in the locality. Dongola locality is divided into five administrative units: Karma, Argo, Alhafeer, East Nile and Old Dongola. Within each administrative unit one village was selected purposively on accounts of being a big fennel producer.

Proportional numbers of fennel's farmers from each village were chosen randomly. Descriptive statistics, gross margin analysis and Cobb - Douglass production function were used to reach the objectives (Heady and Dilon, 1961). The linear form (log_{10}) of the Cobb-Douglass production function is as follows:

$$logY = a + b_1 logx_1 + b_2 logx_2 + b_3 logx_3 + b_4 logx_4 + b_5 logx_5 + b_6 logx_6 + e$$

Where:

Y= fennel total production in kg, a=intercept,
b_1-b_6= regression coefficients to be estimated,
X_1=irrigation numbers, X_2=labor (man days),
X_3=seed rate (Kg/ha), X_4= finance (SDG)
X_5= pesticide (litre/ha)
X_6= sowing date (dummy variables, pre-sowing date = 1, optimal sowing date= 2, post sowing= 3),
e=random disturbance term.

Results and Discussion

Many aspects pertaining to the production of fennel in the study area were discussed. These include: socio-economic characteristic of farmers, costs and net returns, and production function.

Socio-economic characters of fennel producers in Dongola locality

Results revealed that, the majority of fennel producers, in Dongola locality, are in the active age group, highly specialized, and experience in agricultural activities (more than 10 years), owned their land (72.5%), has a large family members that help in farms activities and owned their land (Table 2). Yet, fennel yield in the locality is very poor. The meager productivity might be attributed to the fact that, the majority (64.70%) of the producers had low education level or illiterate, as presented by the percentage of illiterate (8.40%), informal Islamic schools (56.30%) and basic formal educational level (35.30%), inaccessibility to the extension services, and consequently, the adoption of traditional methods of productions these results confirmed by (Ahmed, 2008) and (Mohamed, 2000).

Costs, returns and profits of fennel production in Dongola locality

In calculating production cost, the following items were considered: land preparation, agricultural practices and agricultural inputs (Table 3). It is cleared from Table 3 that, the total costs of fennel production were relatively high (2462.40 SDG/ha) with taxes and Zakat representing the main cost item contributing substantially to the total costs 27.2%. Irrigation costs was the second item that contribute significantly to the total costs (16.8%). This particularly true if known that almost all agricultural schemes in the Northern State are irrigated by pumps from the Nile and/or well (Tawfeeg, 1999). Farmers usually try to minimize the irrigation costs, such as fuel, pump maintenance, labor, fuel and lubricants to an acceptable level through reducing the watering numbers by one from the recommended packages (Mohamed, 1996), without consideration of the negative effects on crop production. This confirms the finding of (Elfeil and Babiker, 2001) in their study of wheat, faba bean and sorghum production in the Northern State of Sudan; they found that farmers in the Northern state usually reduced their agricultural input to cope with the increasing input prices.

Table 2: Socio-economic characteristics of the farmers in Dongla Locality

Items	%	Items	%
Age:		**Land Type:**	
15-30	33.0	Owned	72.5
30-45	37.5	Rented	10.8
45-60	29.5	Governed	16.7
Total	100.0	Total	100.0
Education Level:		**Family Members:**	
Illiterate	8.4	1-5	69.2
Khalwa	56.3	5-7	20.0
Basics (primary + intermediate secondary school)	35.3	7-10	7.5
University	0.0	10 and above	3.3
Total	100.0	Total	**100.0**
Marital Status:			
Not married			34.2
Marriage			65.8
Total			**100.0**

Other cost items in descending orders were the manual harvesting cost (14.00%), land plough by machine and/or oxen (12.3%), and fennel seeds (7.5%). Many farmers (57.50%) in the study area used to adopt different techniques to lessen their cost, most of which revolve around delaying sowing date to the end of November or early December, and reducing seed rate to 22 Kg/ha and fertilizers quantity to 56 Kg/ha, and watering numbers (Field survey, 2010). The recommended and released packages by the Sudanese Agricultural Research Corporation (2009) for the sowing date, seed rate and fertilizers rate are mid-November, 30 Kg/ha and 119 Kg/ha, respectively. These results come in line with (Elhori et al, 2013) and (Iqbal et al, 2015) in their study of potato production in the Northern State of Sudan and potato production in Okara district- Pakistan; they mentioned that, farmers in the State usually trim down their seed rate and delay their sowing date to decrease their costs. On the other hand, the average fennel productivity in Dongola locality was found to relatively poor (1.19 ton/ha) compared with the state level research station (2.5 tons/ha). Many factors might be responsible for that, the most important of which might be, reduction of the released irrigation numbers, lower amount of seeds rate, delay the sowing date and farmers' low education level. The return/ hectare is found to be SDG 6490. Gross margins analysis revealed that, farmers gain good and encouraging net return (4026 SDG/ha) that might push them to continue in the business in the future. The return /SDG invested, which equivalent to SDG /TVC, was found to be (1.65) indicates that this business is very profitable as each one SDG invested gained a net return of 1.65 SDG.

Fennel production function in Dongola locality

Table 4 shows that, the adjusted R^{-2} of the Cobb-Douglass production function was 0.51%, implying that 51% of the total variation in fennel production was explained by the explanatory variables in the model. The F-statistics which was highly significant (p=0.01) imply that, the explanatory variables were collectively important in explaining the variation in the fennel production.

Results revealed that, the effect of each of the explanatory variables; irrigation numbers, seed rate, finance and pesticide on fennel production were positive and highly significant (0.01% and 0.05%). This means

that a one percent increase of each of the explanatory variables increases fennel production by their corresponding elasticity. This result indicates that, farmers in the study area used their inputs in inefficient manners. These particularly true, if known that farmers in the state reduced their seed rate by 75% from the optimal package. According to the authors' field survey 2009/10, many factors are responsible for the reductions of the used inputs, among them are: expensive inputs, lack of enough fund, poor extension services...etc. These results coincide with the findings of (Elhori and Babiker, 2009) in their study of the optimum winter cropping pattern in the northern state, Sudan. They found that, there were high significant difference between the applied reduced watering numbers and the recommended one for all crops produced in the Northern State. On the hand, the coefficients on labor and sowing date were found to be highly significant (0.01%) and (0.10%) respectively, but with negative sign. The negative relationship indicates the over usage of the labor force, particularly family members, in farmers' small sized farms. They also indicate that, farmers do not stick to the recommended sowing date.

Conclusion

Based on the result obtained the low education level of farmers, inefficient use of resources especially: sowing date, sowing rate, fertilizer quantity, irrigation number and traditional seeds used were the major direct contributors to lessen fennel yield. These results suggest improving the technical knowhow of the farmers (strengthening of extension services), provision of microfinance to use an improved seeds and to encourage farmers' adoption of the technical packages and reducing taxes.

Table 3: Percentage distribution of costs, returns and profits of fennel Production in Dongola locality

Cost item	Cost (SDG/ha)	%
Land preparation:		
Land plough	93.60	3.80
Land leveling	105.60	4.30
Ridges and canals	103.20	4.20
Total	302.40	12.30
Agricultural practices:		
Sowing	88.80	3.60
Irrigation	412.80	16.80
Weeding	148.80	6.00
Harvesting	345.60	14.00
Total	996.00	40.40
Agricultural Inputs:		
fennel Seeds	184.80	7.50
Fertilizer	156.00	6.30
Pesticide	153.60	6.20
Total	494.40	20.00
Taxes and Zakat	669.60	27.20
Total production costs	**2462.40**	**100.0**
Gross margin of fennel production:		
Average yield (tonha)	1.19	
Average price (SDG/ton)	5454	
Average revenue (SDG/ha)	6490.26	
Average gross margin (SDG/ha)	**4025.86**	

One US$ =3.1 SDG

Table 4: Fennel production function in Dongola locality

Items	Coefficient	t-value
Intercept	24.75	-
numbers Irrigation	0.29	4.16*
Labor	0.28	3*3.8
Seed rate	0.38	*5.18
Finance	0.12	1.77**
Pesticide	0.14	1.87**
Sowing date (X6)	-0.50	1.50***
F-ratio		18.714*
R^{-2}		0.514

* Significant at 0.01% level, **Significant at 0.05% level, ***Significant at 0.10% level

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دالة إنتاج و ربحية محصول الشمار (Foeniculum vulgare) بمحلية دنقلا، الولاية الشمالية، السودان

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المستخلص-:

هدفت هذه الدراسة إلي تحليل إقتصاديات محصول الشمار في محلية دنقلا بالسودان، من خلال إيجاد الخصائص الإقتصادية و الإجتماعية لمزارعي المحصول و العوائد و الأرباح و إستنباط دالة إنتاج المحصول. تم إستخدام أسلوب العينة المتعددة العشوائية لجمع البيانات من 120 مستهدف بواسطة استبيان جمع في موسم 2010/2009 . الإحصاء الوصفي و الربحية الكلية و تحليل الإنحدار هي الأساليب التي أستخدمت للوصول للأهداف المذكورة. أوضحت النتائج أن مزارعي محصول الشمار في الولاية يستعملون مواردهم بطريقة غير كفؤة. كل المدخلات استعملت بصورة أقل من تلك المطلوبة بصورة مثلى، بالرغم من ذلك كسب المزارعون أرباح مشجعة (1300 دولار/ هكتار). أوضح تحليل الإنحدار أن عدد الريات، و معدل البذر، و التمويل، و المبيدات، هي العوامل الأساسية التي أثرت على إنتاج محصول الشمار. هنالك مساحة كبيرة لتحسين الإنتاجية / الربحية إذا تم تبني بعض المقاييس. هذه المقاييس تدور حول تحسين معرفة المزارع التقنية (تقوية خدمات الإرشاد) و تسهيل الحصول على القروض الصغيرة و تقليل تكاليف الإنتاج من خلال كهربة المشاريع الزراعية وتبني الحزم التقنية و إزالة أو تقليل الضرائب.