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Instructions to Authors

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Book:

Fitter, A.H. and Hay, R.K.M. (2002). Environmental Physiology of Plants. (2^{nd} Edition), Academic Press, London, pp. 120- 128.

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Conference proceedings:

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Examples of some common abbreviations: Time: min, hr, sec; Length: km, m, cm, mm; Mass: kg, g, mg, µg; Concentration: g/cm^3, g/L, mg/L, µg/L, ppm; Volume: cm^3, L, mL, µL

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Preface

Wise management of crop inputs, particularly fertilization, pest, disease weed and irrigation management, will have a massive future bearing not only on crop profitability but also on land and other resource conservation and agricultural sustainability. Regional environmental condition varies edaphically and climatically along the extended parts of Sudan and in same way in other parts of the world. This is why in every specific region we will see an extensive research work covering all these themes to deal with the diverse nature of biological subjects.

Crop research always provide solutions to biological problems. But due to economic and social context complications, the success of research initiatives is strongly dependent on cooperation between natural, economic and social science disciplines, as well as strongly needed cooperation with local interest groups.

In volume 6 (1) of the Nile Journal for Agricultural Sciences we have reviewed a number of subjects dealing with different issues of agricultural sciences. We promise that with coverage of regional issues we will not underestimate broader national and worldwide concerns. Between these parameters and some way beyond them we hope to fit thematically with the standards of the journal.

Editorials

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Research paper

Potentials of Wheat Production and Competitiveness of Prevalent Crops in the Irrigated Farming System of the River Nile State, Sudan

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Abstract

In the River Nile State of Sudan, farmland and irrigation water are the main resources to attain sound crop combinations and sustainable farming systems, whereby resources use efficiency and optimization of available fundamental resources is needed. The broad aim of this research, based on competition indicators with respect to the available agricultural resources use (i.e. land and water) was to determine the promising crop combination taking on board alfalfa and wheat in terms of sustainability of farming system. The analysis depended on structured survey questionnaires and field observations in the area of the study where surface irrigation by pumps from the River Nile is predominant forming the major water supply choice. Integrated techniques comprising economic and hydrologic techniques are applied to assess land and irrigation water use in the State. Descriptive statistics including quantile analysis of the crop water applied and crop water requirements were applied. GAMS, CropWat4 and SPSS have been used to assess the irrigation water performance. The study findings represent the suitable cropping systems for exploiting the available agricultural resources where alfalfa was more competitive than wheat.

Keywords: Alfalfa, wheat, multi-cropping, competitiveness

إمكانيات إنتاج القمح والقدرة التنافسية للمحاصيل السائدة في نظام الزراعة المروية في ولاية نهر النيل، السودان

الجيلانى عبد الحفيظ احمد وحامد حسين محمد الفكي

مركز البحوث الاقتصادية والسياسات الزراعية، هيئة البحوث الزراعية

المستخلص

في ولاية نهر النيل بالسودان، تعد الأراضي الزراعية ومياه الري هي الموارد الرئيسية لتحقيق التركيبة المحصولية السليمة في نظام الزراعة المستدامة، حيث يلزم استخدام الموارد بكفاءة وتحسين الموارد الأساسية المتاحة. كان الهدف العام من هذا البحث، استنادًا إلى مؤشرات المنافسة فيما يتعلق باستخدام الموارد الزراعية المتاحة (أي الأرض والمياه)، هو تحديد تركيبة من المحاصيل الواعدة التي تحتوي على البرسيم والقمح من حيث استدامة نظام الزراعة. اعتمد التحليل على استبيانات المسح الحقلي والملاحظات الميدانية في منطقة الدراسة حيث يسود الري السطحي بالمضخات من نهر النيل والذي يشكل الاختيار الرئيسي لإمدادات المياه. تم تطبيق حزمة متكاملة للتحليل تشتمل على طرق اقتصادية وهيدرولوجية لتقييم استخدامات الأراضي ومياه الري في الولاية. تم استخدام الإحصاء الوصفي بما في ذلك التحليل الكمي لمياه المحصول المطبقة والمتطلبات المائية للمحاصيل قيد الدراسة. تم استخدام برنامج الكمبيوتر للنماذج الجبرية GAMS وبرنامج الكمبيوتر لتقييم المتطلبات المائية للمحاصيل من مياه الري CropWat4 وكذلك برنامج التحليل الإحصائي SPSS. تشير نتائج الدراسة الى النظم المحصولية المناسبة لاستغلال الموارد الزراعية المتاحة حيث كان البرسيم أكثر قدرة على المنافسة من القمح.

كلمات مفتاحية: البرسيم، القمح، المحاصيل المتعددة، التنافسية

Introduction

In Sudan, the assessment of winter field crops combination is considered crucial. The Winter season is ranked as the top and principle season for the River Nile State' farmers in terms of agricultural production. The summer and autumn "*demira*" seasons come thereafter due to some environmental aspects that give high advantages for the winter crops. An evaluation of competitiveness between alfalfa (*Medicago sativa L.*) and wheat (*Triticum aestivum*) was carried out to assess farm resources use as well as productivities of the crops under study. Alfalfa is a perennial legume crop and often used in crop rotations of farming system throughout north and middle regions of Sudan to supply fodder and thereby also provides nitrogen for subsequent cereal field crops. It has a significant contribution to the farm sustainability, household food security and income; that is why it called "Queen of the Forages". Among the dominant crop combinations in North Sudan, alfalfa is usually grown for three to five production years and harvested mechanically or manually according to the farm size. While wheat is considered as one of the main strategic crops in the country, it ranks after sorghum and before millet, contributing to rural and urban livelihoods and food security. Over the past two decades, wheat production, which is almost entirely irrigated, has been fluctuating and declining due to declining yields and soaring input costs. Since the end of 1990s, the government liberalized agriculture and removed all support programs. These new policies have affected a lot of wheat growers to consider wheat as a secondary crop and extend the lucrative cash crops areas, such as legumes, pulses and vegetables.

The overall average area under wheat for the period 2013 to 2017 was about 454,000 feddan allocated among the main supplier states namely, Gezira (256,000 fed), Northern State (84,000 fed), River Nile (39,000 fed), New Halfa (38,000 fed) and White Nile (37,000 fed). This research was carried out in the River Nile State (RNS) at the northern part of the country. The RNS is considered as one of the most promising states in the country as it enjoys relatively cooler winter season "*Shetwi*" and is endowed with fertile alluvial soils. It also has a comparative advantages compared to other parts of Sudan in producing relatively high-value field and perennial crops (citrus, mangos, dates, wheat, faba beans, certain spices and medicinal plants). The State accommodates numerous types of irrigated schemes such as the public irrigated schemes, foreign investmet schemes, agricultural companies, private and cooperative schemes with different production relationship systems. These schemes are regarded as main potential ones for developing agriculture in general and winter season crops in particular due to their high acreage share, capital availability and machineries while hosting high numbers of farmers.

The research sellected El-Zeidab Public Irrigated Scheme as one of the study cases representing the conventional irrigation systems in the state. It is the oldest and biggest one belonging to the State Ministry of Agriculture. The total area of the scheme is about 22,000 feddans.

Beside El-Zeidab scheme, the study has choosen Elkafaa-Al-Rajhi Scheme representing the modern irrigation systems in Berber locality of the RNS. The location of Elkafaa-Al-Rajhi scheme is considered as an appropriate site to apply modern farming system and advanced irrigation technologies (i.e. pivot sprinkler irrigation system) and holds potential to develop agricultural production. The scheme is one of the recent foreign investment schemes in the RNS located at about 350 km north of Khartoum. It was established in 2012 by Al-Rajhi International Group for Investment of Saudi Arabia. The total area of the scheme was originally about 100,000 fed devoted for grain and fodder production. The scheme is applying international experience of agricultural development and advanced irrigation technologies for agricultural production.

These problems that contribute mainly to the low levels and fluctuations of winter crops yield include inadequate practices forming the crops technical packages used by farmers, misuse of agricultural resources, stress caused and inflicted by changing environmental and climatic conditions especially temperature, beside the widespread of different diseases, insects, pests, weeds and power failure caused by lack and high cost of fuel and spare parts to operate the pumps. Numerous research mentioned that the high cost of production coupled with low levels of crop yields and instable source of power has contributed to difficulties faced by growers to realize the full potential in the State. In addition, development is constrained by serious limitations in two basic resources namely, land and water. Regarding irrigation water in the State, there are many hindrances contributing to inefficiency of irrigation water use and affecting crop production in the irrigated schemes in RNS such as inadequate supply of irrigation inputs at the proper time and right prices.

Generally, improvement of the farming systems in the State considering climatic change and food security and farming system sustainability of the local populations is regarded as a great challenge for researchers, policy makers, scientists, agricultural administrators in public and

private sectors, related organizations and investors. Finally, this study looks to determine the promising crop combination including alfalfa and wheat in terms of resources use advantages in the form of economic returns and crop yields.

Methodology

This research was carried in the River Nile State. The climatic conditions of the State allow the production of a wide range of perennial and seasonal crops. The farming system in RNS includes mainly four types of agricultural schemes namely, private or individual, cooperative, public pump and foreign investment irrigated schemes. Tropical and sub-tropical fruits grown include dates, citruses, mango, banana and guava. Soils are alluvial, which are generally fertile, are made up of loamy and silt deposits, generally well drained non-saline and non-sodic (Ahmed, 2004). Many studies mentioned that the RNS has been assumed to have a comparative advantage in field cash and food crops production namely, legumes, vegetables, cereal and spices beside perennial crops including alfalfa. This assumption is based on the State's favorable climatic conditions, vast endowments such as land, permanent sources of irrigation and accumulated experiences of skilled farmers. Beside the River Nile, Atbara River and underground water are other important direct resources of irrigation water in the agricultural sector of RNS. Although the RNS is characterized by past comparative advantages, but the last decade witnessed frequent debates about the deterioration of agricultural production, which might manifest itself in numerous indicators such as low crop productivity, high cost of production, inadequate credit, and markets and prices instability. This situation raises the conviction that the stability of the irrigation sub-sector forms a major driver for achieving food security, poverty alleviation and improving the livelihood of the farmers of the scheme.

The study has been based on two case studies namely, El-Zeidab public irrigated scheme and Elkafaa foreign investment irrigated scheme. Elkafaa scheme is characterized as a modern scheme applying modern and full-mechanized systems. Its production system is based mainly on annual field crops such as grains, pulses, fodder and other agricultural activities, while the farming system of El-zeidab scheme is distinguished mainly as semi-mechanized system.

The prevalent crop combination in the RNS often includes field crops, perennials and animal production activities. This research depends mainly on primary data from areas of the study, beside secondary data from relevant official sources. The method selected for primary data collection was direct personal interviewing of the sampled respondents by using structured questionnaires. The primary and secondary data were collected for season 2015/2016 to compile information concerning the operation of the schemes under study.

Sample size

In order to secure reasonable precision, stratified random sampling techniques was applied based on sample size proportional to the relative sizes of the targeted groups in the public irrigated scheme, where primary data was collected through direct personal interviewing by using structured questionnaires for (70) randomly selected respondents through probability proportional method, taking into consideration limitations in survey budgets, the time factor and other available facilities. On the other hand, a comprehensive secondary data set was obtained from Al-

Rajhi-Kafaa irrigated scheme. A few hindrances were faced in the two case studies; firstly, in El-Zeidab public scheme which was still lagging behind with inadequate infrastructure made the movement and the field work implementation over the study area rather difficult.

The tenants of the scheme, often skeptic about the research work, the information flow from them needed patience and smart enumerators. Some of the tenants were uncertain about, and had mistrust in the aims of research work, thinking that it aims to raise taxes so their response was sometimes very poor. Some others reported that numerous research work had been done in their tenancies without tangible returns in the scheme.

Secondly, Elkafaa scheme is regarded as new scheme in the area of study when compared to the public ones. However, the accessibility for the required information and other technical data is not reported in a proper manner.

Analytical techniques

Numerous techniques were applied to achieve the goals of the study. Descriptive statistical analysis was used. In this part of the analysis, graphical, frequency distribution and statistical analysis was applied. The computation of the crop water requirements (CWR) of any crop requires estimation of its crop coefficient values. The Food and Agriculture Organization's (FAO) Penman-Monteith (PM) method was recently developed to assess ETO values from a hypothetical reference crop that were more consistent with the actual CWR and has been recommended by the FAO as the standard method for CWR calculation designed in the software program CROPWAT4. For the on-farm water-use efficiency (FWUE), the research has adopted ICARDA's (2005) concept to evaluate the efficiency of on-farm water use. The concept of ICARDA concerning FWUE has been developed to address farm levels where complexity exists. The definition of FWUE by ICARDA is a ratio of required irrigation water to produce a specific output level to the actual amount of water applied by farmers. Linear programming (LP) analytical technique also was employed using GAMS (General Algebraic Modeling System). LP is a mathematical programming technique useful for detecting the best allocation of the farm scarce resources. The model seeks the maximization of gross margins as the underlying objective function:

$$Max\ \pi = \sum_{j=1}^{n} Z_j X_j \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Such that:

$$\sum_{j\ 1}^{n} \alpha_{ij} X_j \leq b_i, \text{ all } 1 \text{ to } m = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

And:

$$X_j \geq 0, \text{ all } j = 1 \text{to } n \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where*:*

π = is objective function value per year;

Xj = Level of the j^{th} the farm activity, such as the acreage of wheat grown and n denotes the number of possible activities; the j=1 to n;

Zj = gross margin of a unit of the j^{th} activity (SDD/feddan) ;

Aij = quantity of the i^{th} resource available (i.e., days of labour or other required quantities of inputs) required to produce one unit of the j^{th} activity;

M = Denotes the number of resources; then i = 1 to m;

Bi = Amount of the i^{th} resource available (e.g. cubic meter of irrigation water, land area in feddans, days of labour or other required quantities of inputs).

The objective is to find the cropping system (defined as a set of activities levels Xj, j = 1 ton) that has the highest possible total gross margin π, but doesn't violate any of the fixed resource constraints or involve any negative activity levels.

Equation (1) is the objective function, which maximizes the gross margins from one feddan of field crops.

Equation (2) shows the limits on the levels of the available resources (i.e., cubic meter of water, feddan of land, days of labour or other required quantities of inputs) that the tenant can apply to produce the mentioned crops.

Equation (3) which is a non-negativity condition, states that all resources used in the production process and output must be equal to or greater than zero, meaning that negative use of resources and negative production is not allowed.

The research adapted the regression model of Heady and Dillon 1961 adopted by Ahmed (2009). The model is based on Cobb- Doughas production function and others. For Multiple Regressions; according to Ahmed (2009), that multiple regression is measuring the change in one variable while holding the effects of other variables constant. It consists of two or more independents variable. The multiple regression model contains several explanatory variables, is considered as a logical extension of simple regression model. According to Mohammed (2013), that the production function in theory, would include inputs of sources such as variable soil nutrient, pest and disease that might influence yield and because impossibility of specifying all of their variables separately, some may be lumped together into a broad category, such as land and labor. Other variables which are considered unimportant can be ignored. Production function can be represented by Table (s), schedule (s), all mathematical equations, to determine maximum output that can be produced from specified combination of inputs given in the existing state of technology, and the output will change when the quantity of inputs changed. Mathematically the production function can be represented as follows:

$$Qi = f(x_1, x_2, \ldots x_n).$$

Where:

Qi = Output of the product;

x_1 = Inputs used i = 1 ton

The study also applied partial budget analysis to assess the cost and returns of the crops under the study. Statistical tools were used to analyze the main cost items of potato production to determine

the significant variables. According to Abbas and Elamin (1997), there are three broad types of situation in which budgeting may be called for:

i. A comparatively minor change in practice.

ii. A drastic change in farming.

iii. Starting up on a new farm.

Partial budget analysis was used to analyze field data survey and the economic evaluation of the effect of new recommended package. It organized data and information on yield, costs of inputs, husbandry practices and resultant benefit of crop output. Table 2 shows the calculation of partial budget analysis according to the following criteria:

1. The gross revenue (GR); was calculated by multiplying the farm gate price of the crop by the crop yield,
2. Total variable costs (TVC); is calculated by multiplying the quantity of input (material or practice) used by its price,
3. Gross marginal revenue (GMR); was calculated by subtracting the gross revenues minus the total variable costs. The difference in gross marginal revenues of adopters and non-adopters indicated the net monetary return that resulted from use of the technology. The general mathematic expression is:

   Gross marginal return = Gross revenue - total variable costs

$$GMR = GR - TVC \quad (1)$$

Where:

GMR Gross marginal return (revenue),

GR Gross revenue,

TVC Total variable cost

The study also applied partial budget analysis to assess the cost and returns of the crops under the study. The basic data used to compute gross returns per fed are output values, while gross margin per fed was calculated by subtracting the average total operation cost (variable costs) from the average total returns. The general mathematical form for the gross margin calculation per crop is as follow:

$$GM = GR - TVC$$

Where:

GM= Crop gross margin per feddan in SDG,

GR= Crop gross revenue per feddan in SDG, and

TVC= Crop total variable costs per feddan in SDG.

Results and discussion

The design of a comprehensive crop combination for each season especially the winter season in River Nile State (RNS) is considered as a key factor to obtain a successful production and sustainable farming system. The winter season crop combination in RNS implies mainly cereal and legumes crops. In general, non-legume crop is considered a suppressing crop in annual legume/non-legume intercrop system (Guiguo *et al.*, 2011). However, the performance of perennial legume and annual cereal intercropping varied by intercrop pattern (Abdel Magid, 1991). The competition between alfalfa and wheat crops in northern Sudan is not inter-specific competition; it is not concerning above-below ground competition, the competition here is known as the interaction between two crops in one crop combination that affect the decision of producers to allocate their available agricultural resources to each crop of the targeted crop combination. The competitive abilities of component crops can be defined in terms of crop yield and returns; hence, the dominant crop directly influences the apparent performance of the crop combination communities. Thus, the crop combination competitive behavior is essential to the structural stability of the cropping pattern and farming system. Further, knowledge of competitiveness can predict yields and returns of crop combination.

The tenants in the agricultural schemes of RNS seek every season to adopt a relevant crop rotation that contributes to irrigation water and land use efficiency as well as soil conservation. They look to manage a reliable crop combination comprising cereal or grains such as wheat and beans or legumes crop like faba bean and alfalfa. However, a successful winter season with high yield for grains and legumes might attain many goals, at least may achieve maximization of resources use which leads to poverty alleviation and food security in the agricultural rural areas of Sudan.

Agricultural resources management in River Nile State (RNS)

Agricultural resources are essential components for crop production. In a world of limited resources, limited sympathy and limited rationality, competition leading to tensions and conflict can arise. In such circumstances, a key responsibility of any society is to ensure the security of its citizens (Richard, 2009). Due to natural resources management complexity and scarcity, rationalizing and optimizing resources use becomes crucial to maximize the benefit from them. The scarcity of agricultural resources is exacerbated by limited agricultural land and limited water available for irrigation in case of expansion in new reclaimed land. Thus, the optimum crop combination should be considered to achieve more than one goal to reach the most efficient crop combination to achieve and rationalize resources consumption in order to increase farm income and save a large amount of irrigation water for expansion. The River Nile State is considered as one of the main suppliers for agricultural production in Sudan. The total area of the state is about 129.744 km^2 (30 million feddans) out of which about 3,249,000 fed is certified land for investment and suitable for multi agricultural activities and production **(**Table 1**).**

However, this research revealed that the performance of resources management for agricultural production in the state is indicated by low efficiency as shown in Figure (1).

Table (1): Distribution of land resources in RNS

Land resource	Area (feddan)
Agricultural Arable land	9,500,000 feddan
Certified land for investment	3,249,000 feddan
Agricultural cultivated land	1,200,000 feddan
Forest land	209,000 feddan
Natural pasture land	48,000 km^3

Source: Ministry of Agriculture in RNS 2017

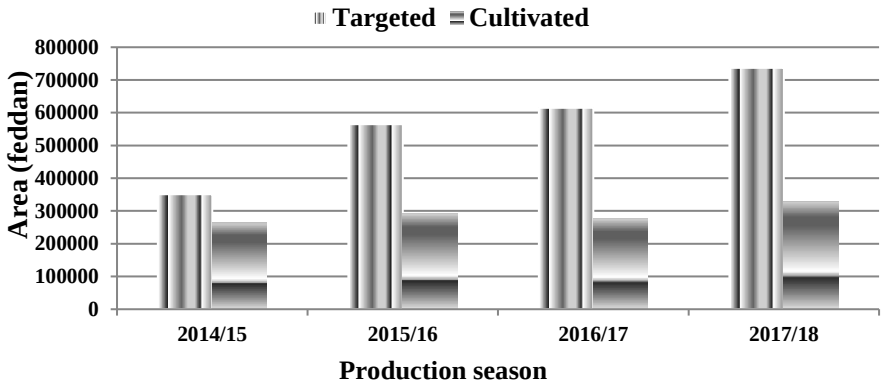


Figure (1): Area gaps between the targeted and cultivated areas in RNS for the winter seasons 2014/15 to 2017/18

No doubt water resources represent one of the essential inputs for agricultural production. Sudan also is endowed with a sizeable amount of surface water resources. The utilization of this water under the umbrella of the Nile Waters Agreement (1959) signed between Sudan and Egypt is based on the average annual flow of 84 billion m^3 measured at Aswan shared as follows: the Sudanese share 18.5 bm^3, Egyptian share 55.5 bm^3, and the losses in Aswan 10 bm^3. In addition, the State has underground water in the Nubian Sand Stone. The River Nile State is one of the relatively rich states in the country in water resources. The main direct resources of irrigation water in RNS are the River Nile, Atbara River, underground water and rains (Table 2).

Table (2): The main direct resources of irrigation water in RNS

Water source	Water amount
River Nile along the RNS	670 km^3
Atbara River	200 km^3
Underground water aquiver	3,16 bm^3
Surface water and valleys from rains	1, 490 bm^3 and 57 valleys

Source: Ministry of Agriculture in RNS (2017)

Cultivated area in River Nile State

The distribution of field crops in the River Nile State season 2016/17 was such that the majority of the total land was devoted to onions, followed by wheat and faba bean, while the lowest percentage was allocated to chickpea. The other crops were ranked as illustrated in Table (3).

Table (3): Cultivated area of crops in the RNS in season 2016/17

Crop	Area (fed)	Production (ton)	Price (SDG/ton)
Wheat	38,281	49766	5500
Faba bean	30,611	10408	17500
Kidney bean	10,875	4133	27500
Chickpea	3,728	1492	19000
Potatoes	14,773	92332	28000
Onions	54,184	915710	3250
Vegetables	17,315	110555	22200
Fodders	26,086	42816	900
Spices	6,086	59244	85575
Sorghum	12,917	30799	3830

Source: Ministry of Agriculture in RNS 2017

On the other hand, available information unveils that the total cultivated area of Al-Rajhi-Kafaa scheme is about 19,500 feddans distributed among 156 pivot sprikiler units. The allocation of the field crops in the scheme was such that 40% of the total cultivated land was occupied by wheat, followed by 30% for alfalfa, while 20 and 8% went for maize and sunflower, respectively. The paper observes that most of the cultivated area was covered by cereal crops which are very exhaustive to soil fertility, while legumes and vegetable crops formed a limited area of the scheme indicating negligence of land improvement to produce food security products and of soil conservation.

The majority of these crops are cultivated as winter crops with exceptional cases for some crops that could be produced in winter and summer seasons, namely maize, fodder, and vegetables. Furthermore, sorghum in El-Zeidab scheme is usually sown at the end of the summer season (September) to be harvested in the middle of the winter season (January), while sorghum and onions are grown in April after wheat harvest and continue to be irrigated with wheat. The harvested crops are used either for domestic consumption and/or as cash crops.

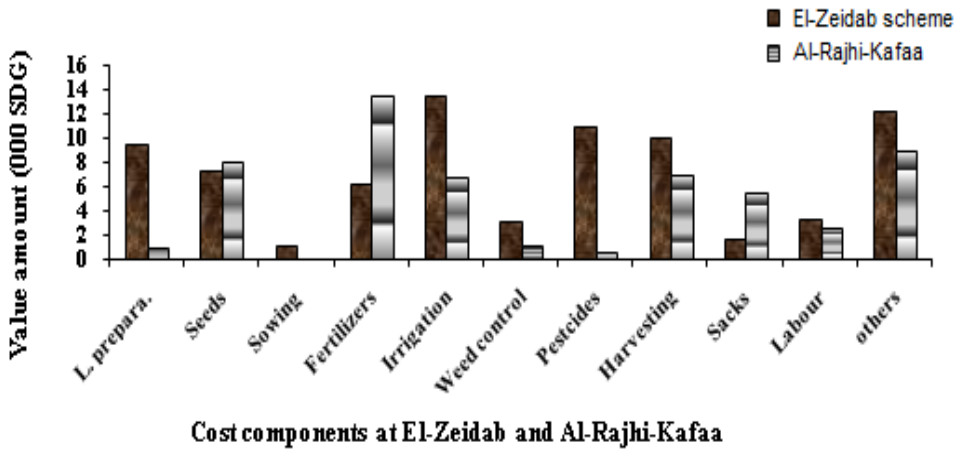
Wheat and alfalfa crops production in RNS

Agricultural production relations in River Nile State are variable. Those in the private pump schemes are unique. The small farmers there have to pay part of their produce in return for irrigation water alone, or in some cases, irrigation plus other services provided by the owner of water pump. The share of the small farmer should pay usually differs according to the crop grown, land ownership, soil quality and obligations agreed upon between the two partners (Ijami, 1994). The public schemes in RNS include holdings of various sizes whose operators may be owners or tenants. Water is delivered to the land by the administration of the scheme which owns the pumps and canals of these schemes, and the farmers are billed the cost of water. In RNS the most dominant procedure is allocation of one seventh of the crop output for the land, while the remaining output is shared equally between the pump owner and the small farmer. Based on this agreement, and according to whether the crop grown is a low or a high value crop, the pump owner may pay or share the cost of inputs with the farmer such as fertilizer and pesticides (Ijami,

1994). The production relations in the schemes of the study are absolutely different. In El-Zeidab scheme the relation has been based on a water rate system subject to an agreement between farmers and scheme administration. The scheme water charges differ between field and perennial crops. In Al-Rajhi-Kafaa scheme the situation is different as mentioned early; however, the crop production operations and processing has been are managed by the scheme administration as mentioned before.

Analysis of wheat and alfalfa costs and returns

Generally, economics of production is regarded as fundamental role in enterprise and farm management. Production costs are known as the cost of inputs, labour, services, and the management used in producing a particular commodity or crops. Numerous researches indicated that the high cost of crop production in the River Nile State has contributed to low profit (Ahmed, 2009). The research observed that that most of the tenancy operations in El-Zeidab scheme were handled by the scheme's farmers and/or their relatives, while hired labours were usually needed for labour intensive operations such as land preparation and harvest. In large scale private schemes, the situation is different. In this study case of Al-Rajhi-Kafaa scheme farm machineries are used for most of production operations with low numbers of labours. Figure (2) illustrates the cost components within the sequence of production operations of annual crops in the two study schemes. It is clear that the majority of the variable cost components of producing annual crops in El-Zeidab scheme exceeded those at Al-Rajhi-Kafaa. The high cost in the public scheme of RNS could be justified with such as lack of application of advance technologies as well as the large scale of production. Generally, Al-Rajhi-Kafaa scheme is characterized by being fully mechanized with large scale production, contributing significantly in decreasing the operation cost of the scheme in contrast to the case of El-Zeidab scheme.



Source: Field Survey 2017

Figure (2): Average cost components for field crops in El-Zeidab and Al-Rajhi-Kafaa

The research employed gross margin analysis technique to assess wheat and alfalfa returns. Gross margin is considered as one of the good indicators of how profitable a farm or a firm at the

most fundamental level. Farms or enterprises with high gross margins will have abundant resources to invest in future activities such as production and marketing promotion.

The past few decades have witnessed the increase of global demand for alfalfa fodders and wheat grains with increasing awareness of their value and benefits. Gross margins for alfalfa and wheat under study were assessed in Table (4).

Table (4): **Gross margin analysis for wheat and alfalfa at Al-Rajhi-Kafaa and El-Zeidab**

Budget component	Alfalfa budget analysis Al-Rajhi-Kafaa (SDG/year)	Alfalfa budget analysis El-Zeidab (SDG/year)	Wheat budget analysis Al-Rajhi-Kafaa (SDG/season)	Wheat budget analysis El-Zeidab (SDG/season)
Production cost (SDG/fed)	4,200	3,800	3,626	3000
Average yield (kg/fed)	7,560	6,206	2,300	1,080
Average price (SDG/kg)	3.00	3.0	5.0	5.0
Gross returns (SDG)	22,680	18618	11,500	5,400
Gross margins (SDG)	18,480	14,818	7,874	2,400

Source: The field survey 2017

Gross margins of the two crops were positive in the schemes of the study as depicted in Table (4), but with variation. Al-Rajhi-Kafaa could attain the highest gross margins for alfalfa reaching about SDG 18,480 compared to SDG 14,818 obtained by El-Zeidab tenants. The gross margins for wheat reached about SDG 7,874 and 2,400 for Al-Rajhi-Kafaa and El-Zeidab, respectively. The differences in gross margins of wheat and alfalfa are mainly due to variation in the crops productivities. Furthermore, with yield improvement of wheat and alfalfa crops grown in El-Zeidab public scheme, still higher gross margins can be obtained in case they introduce advanced technology and effective agricultural management.

In general, farm income in the public irrigated schemes of RNS is low. Wheat and alfalfa growers in these schemes need more awareness regarding modern technologies, farming system management and market promotion within marketing issues. The research revealed that, on one hand the alfalfa growers in the River Nile State may replace low income crops to expand alfalfa cultivated area due to its high returns. On the other hand, the government considers wheat as strategic crop and encourages the crop growers to produce it.

Irrigation water management in El-Zeidab and Al-Rajhi-Kafaa

The demand for good-quality water is continuously rising owing to the rise in the population, intensive agricultural practices, industrialization and overall rise in living standards (Srinivas *et al*, 2009). Many researches unveiled that irrigation water in agriculture represents about 70% of global fresh water use. The method developed in this research utilizes the statistics obtained from Ministry of Agriculture of RNS, Al-Rajhi-Kafaa scheme reports and economic modeling to design a more reliable data set for RNS and resources use in its irrigated schemes by combining as far as possible the obtained data from the areas of the studies, prevalent cropping patterns and irrigation systems to evaluate the amount of cultivated land and water applied.

Crop water requirements in the area of study

Extensive researches were carried out in the field of irrigation water use for a range of perennials and field crops to facilitate the accurate estimate of irrigation requirements of the mentioned crops on the basis of climatic and standardized crop data. Combined with soil water balance calculation, a range of computer programs such as the FAO CropWat4 program exist to determine irrigation schedules, assuring accurate and efficient water supply. The predominant conception of irrigation requirements (IR) refers to the water that must be supplied through the irrigation system to ensure that the crop receives its full crop water requirements. This research adopted the Food and Agriculture Organization (FAO) method for computing crop water requirements (CWR); from the calculation of crop coefficient (kc) to the estimation of irrigation diversion requirements. Using the CropWat4 associated database of climatic data for key stations around the world for the main annual crops namely, wheat, maize and alfalfa in the area of the study. The obtained results (Table 5) showed that the CWR for the field crops in the areas of the study vary according to the prevalent climatic factors.

Table (5): Determination of CWR/ha in area of the study

Crop	ETo (m^3)	Kc	CWR (m^3/ha)
Wheat	1.81	1.82	5,750
Alfalfa	6.00	1.7	17,460

Source: calculated by the authors (2018)

Irrigation water supply in the schemes of the study

The amount of on-farm supplied water was already computed by specialists working at the Ministry of Agriculture and Irrigation in the State. This quantity is estimated as 588 mm /fed per watering for the public irrigated schemes in the State including about 3% losses for both seasonal and perennial crops. On the other hand, the applied irrigation water amount was adjusted according to type of crop and hence was calibrated for the crop combination in Al-Rajhi-Kafaa scheme. The main source of irrigation for El-Zeidab and Al-Rajhi-Kafaa schemes is mainly the River Nile. Irrigation water supply at Al-Rajhi-Kafaa scheme is characterized as a daily application and the watering period was in the range of 16 – 20 hr/day for the crops grown in the scheme namely, wheat, maize and alfalfa. The research revealed that the computed irrigation water charge in the Al-Rajhi-Kafaa scheme in season 2016/2017 was 200 SDG for wheat and 1000 SDG for alfalfa, while the impact of rainfall is neglected due to its small amount. The general characteristics of the crops under study are summarized as average quantities (Table 6).

Table (6): Wheat and alfalfa crops basic data in Al-Zeidab public scheme

Crops	Growing Period (days)	No. of Irrigations	Term of irrigation (hours/fed)	Irrigation Interval (days)	Water charge (SDG/fed)
Alfalfa	1460	24	5.5	15	1000
Wheat	114	7	4	15	200

Source: field survey 2017

Wheat stays 114 days while alfalfa stays 1460 days as the longest duration among the dominant crop combination in El-Zeidab scheme. The number of watering varied among the field crops, being about 7 watering for wheat while alfalfa received about 24 watering. The average irrigation interval was 15 days for each of the two crops. The annual water charge was fixed by the scheme administration at 200 SDG for wheat and 1000 SDG for alfalfa. In assessing the on-farm water use efficiency (FWUE) of alfalfa and wheat, the calculated FWUE covered mainly two levels of irrigation: per watering and per season. The annual average water application in Zeidab was 3,756 mm for wheat and 9,023 mm for alfalfa (alfalfa is a perennial crop). The study found that the average water application for the other field crops per season was 8820 mm, 3426 mm and 2,352 mm for onion, sorghum and Abu sabein forage crop, respectively (Table 7).

Table (7): FWUE per watering and season for wheat and alfalfa in El-Zeidab

Crop	CWA (m^3/fed)	FWUE per watering	Over-irrigation (%)	FWUE per season	Over-irrigation (%)
Alfalfa	9023	0.46	54	0.81	19
Wheat	3756	0.41	59	0.64	36

Source: The field survey 2017

Table (7) shows that the FWUE for El-Zeidab field crops are relatively high and indicating increased water demand per watering throughout their growing season. Further, the estimated FWUE of El-Zeidab scheme indicated a wide technical gap between the required amount of water and the actual water supply. Results also unveiled that the FWUEs per watering were 0.46 for alfalfa and 0.41 for wheat, while the FWUE per season amounted to as high as 0.81 for alfalfa and 0.64 for wheat. This shows clearly that the tenants within El-Zeidab surveyed sample over-irrigated their field crops. On the other hand, FWUE in Al-Rajhi-Kafaa scheme was shown in Table (8). The distribution of crop growing periods revealed that wheat stays for 114 days while alfalfa stays for 290 days with a longer duration compared to wheat and other field crops.

Table (8): On-farm irrigation water-use efficiency at Al-Rajhi-Kafaa

Crop	Growing period (day)	Supplied water (m^3/ ha)/year	Annual CWR (m^3/ha)	FWUE /year	% Over irrigation
Wheat	114	8,721	5,750	0.66	34
Alfalfa	290	22,185	17,460	0.79	21

Source: The field survey 2017

The annual average water application for alfalfa in Al-Rajhi-Kafaa was about 8,050 mm exceeding those of all the grown field crops in the scheme due to the same justification in El-Zeidab scheme where the average water application was 2,275 mm for onion as the highest amount, followed by 1.925, 1.750 and 1.225 mm for wheat, sorghum and Abu sabein forage crop, respectively.

Table (9): FWUE per watering and season for the schemes' crops of the study

Scheme	FWUE/ watering	Over/under irrigation %	FWUE/ season	Over/under irrigation%
FWUE El-Zeidab	0.41	(+) 59	0.62	(+) 38
FWUE Al-Rajhi-Kafaa	1.1	(-) 10	1.1	(-) 10

Source: The field survey (RNS) 2017

The FWUE for Al-Rajhi-Kafaa field crops are relatively low when compared to El-Zeidab field crops and also to their water requirements except the case of alfalfa indicating water shortage through their growing season. Further, the estimated FWUE of Al-Rajhi-Kafaa scheme indicated negative technological gaps between the required utilization and actual water application for most of field crops, while FWUE for Al-Rajhi-Kafaa per watering was found to be 0.89 for alfalfa as the lowest FWUE, while it was 1.4 for abu70 forage as the highest FWUE, followed by 1.3, 1.2 and 1.1 for wheat, sorghum and onions, respectively. On the other hand, FWUE per season amounted to as high as 1.3 for abu70 forage; followed by 1.2 for each of wheat and sorghum and 1.1 for onions, while it was as low as 0.9 for alfalfa. This implies that the administration of Al-Rajhi-Kafaa scheme under-irrigated its field crops by 20% as the cases of wheat and sorghum and by 30% for Abu sabein forage, while alfalfa was over-irrigated by 10%. These results showed fundamental policies implications such that, improving FWUE for the annual crops under the schemes of the study to contribute to the overall FWUE in region. The estimated surplus water at Al-Zeidab public irrigated scheme would be sufficient for expansion in new irrigated area in the scheme. The irrigation water supply in Al-Rajhi-Kafaa is, on the other hand, characterized by irrigation shortages for most annual crops.

Water productivity for wheat and alfalfa crops in RNS

Yield and water productivity can be sustainably improved with the application of supplemental irrigation in the rain–fed areas, the adoption of water harvesting in the steppe areas, and the use of improved irrigation systems and schedules in irrigated areas (Shideed *et al.*, 2005). ICARDA (2005) defines water productivity as the ratio of crop production (kg) to the unit of water used (mm) or as the amount of food produced per unit volume of water used, while economic productivity is defined as the net present value of the product divided by the net present value of the amount of water diverted or depleted (defined in terms of its value or opportunity cost in highest alternative use). Generally, ICARDA reports that there are several different ways for expressing water productivity (WP) such as pure physical productivity or combined physical and economic productivity, but the majority of the researchers frequently use the term water productivity as the ratio of physical crop yield and the amount of water consumed. Productivity is expressed as a mass (kg or ton) and the amount of irrigation water as a volume (m^3). The determination of productivity per unit water (WP) for Al-Zeidab and Al-Rajhi-Kafaa annual crops of the study was based on physical water productivity as presented in Table (10). As research facts, numerous techniques can be used to achieve high water productivity, this can be through promoting water use efficiency (WUE) techniques, adopting advanced irrigation technologies for an effective on-farm water use, selection of proper crop combination, cultural practices and adopting suitable crop varieties.

From Table (10) the technical method for assessing physical water productivity derived as kg of output per m^3 of water was generally low for Al-Zeidab field crops while it is high in Al-Rajhi-Kafaa scheme.

Table (10): Yield and WP for wheat and alfalfa in physical and monetary terms

Crops	Yield (kg/fed)	Research yield (kg/fed)	Yield Gap %	WP (kg/m^3)	Water price (SDG)	WP (SDG/m^3)
Wheat (Zeidab)	1,080	2,000	46%	0.29	200	0.05
Alfalfa (Zeidab)	6,206	8,500	26%	0.69	1000	0.1
Wheat (Kafaa)	2,300	2,000	15% (-)	1.1	110	0.05
Alfalfa (Kafaa)	7,560	8,500	11%	11.9	480	0.1

Source: The field survey (RNS)-2017/2018
47.5 SDG^2= 1 US$

Table (10) shows that the water productivity was high for Al-Rajhi-Kafaa wheat and alfalfa crops and low for Al-Zeidab ones indicating very high irrigation water use efficiency under Al-Rajhi-Kafaa modern irrigation systems represented by pivot sprinkler system. This may confirm the ability of advanced irrigation technology to manage irrigation water efficiently.

The main factors affecting wheat and alfalfa production in RNS

a. Factors affecting wheat production in in El-Zeidab scheme

Analysis of resource allocation efficiency can be accomplished by estimating input response or production functions for various crops and examining resources use through production economics analysis. The data were statistically fitted to several algebraic forms of production functions, a few of which were the linear model, the Cobb- Douglas, the Quadratic and the Cubic forms (Ahmed, 2009). One of the models used in this study is based on Cobb-Douglas production function using the primary data of the field survey in the area of study. The model satisfies some of the specific aims of the research as far as the factors affecting wheat and alfalfa production in Al-Rajhi-Kafaa and El-Zeidab schemes are concerned.

In the first model wheat was taken as one of the important and strategic crops in the Northern Region of Sudan due to it is importance in food security, cash and its big area share. Wheat productivity (kg/fed) was taken as dependent variable in this model, while the average of tenants' age, family labour (man-day/fed), field location (km), hired labour (man-day/fed), distance of farm to source of irrigation (km), number of watering (per season), period of watering (hour/fed).

All the variables had the expected signs with their coefficients passing the t-test at different significant levels. The F-statistics of 15.11 was significant. The model is specified in a linear-linear form; hence, the coefficients of the variables represent the corresponding elasticities that indicate the relative change in wheat yield (kg/fed) relative to the change in independent variables. The variables included in the model were found to be significant at different levels as shown in Table (11). From Table (11) the age of tenants has got coefficient of -0.26 indicating a one percent increase in tenants' age will decrease the yield by 0.26%, while the numbers of hired and family labours represent a relative increase of 1 % in hired and family labour will cause a relative increase of 0.94% and 0.40% in yield of wheat, respectively.

Table (11): Regression equation results for wheat in El-Zeidab scheme

Variables	Coefficients	Standard errors	t-values	Level of Significance (*)
Intercept	-13.482	6.220	-3.169	*
Age	-0.264	0.629	-2.7	*
Family labours (man-day/fed)	0.4	0.694	4.013	**
Hired labours (man-day/fed)	0.942	0.509	5.303	***
Farm to source of irrigation (km)	1.12	0.929	8.096	***
distance from source of irrigation to a farm (km)	-0.819	0.000	-7.903	***
No. of watering (per season)	0.421	0.419	2.533	*
Period of watering (hour/fed)	-1.446	0.765	-5.875	***

Source: Computed from the field survey data

R-square = 0.93, Adjusted R-square = 0.88, F-value = 17.87

* = Significant at 90% level of probability.

** = Significant at 95% level of probability.

*** = Significant at 99% level of probability.

The results show that the coefficient of distance from source of irrigation to a farm (km) variable has got a positive sign explaining an increase of yield by 1.120% and the coefficient for the distance from source of irrigation to a farm was found as 0.819 indicating a decrease of yield by 0.819%. Relative increase of 1% in number of watering will cause a relative increase of 0.42% in yield of wheat. While the period of watering per hour/fed has got a negative coefficient indicating a decrease in wheat productivity by 1.446%. The regression analysis concluded that, the mentioned variables in Table (11) represent factors affecting wheat productivity and give impressive indicator to assess the management component and resources use efficiency for field crops in the public and private schemes of River Nile State.

b. Factors affecting alfalfa production in RNS in El-Zeidab scheme

The analysis showed that there are some factors affecting the production of wheat and alfalfa crops in El-Zeidab and Al-Rajhi-Kafaa schemes, by considering the productivity of alfalfa and wheat crops (kg/fed) as dependent variables. In the model alfalfa legume crop was taken as an important and promising fodder crop among the dominant crop combination in the northern region of the country. In addition, a scientific fact is that the crop is considered as essential for farm sustainability and conserving soil fertility due to its ability of nitrogen fixation. As mentioned before, alfalfa productivity (kg/fed) was taken as dependent variable, while the average of tenants' age, family labour (man-day/fed), family size, total farm area, alfalfa area, distance of farm to source of irrigation, citrus area, number of watering (per season), alfalfa seed rate (kg/fed), irrigation interval formed the independent variables. All the variables had the expected signs with their coefficients passing the t-test at different significant levels. The F-statistics was significant. The model is specified in a linear-linear form; hence, the coefficients of the variables represent the corresponding elasticities that indicate the relative change in alfalfa yield (kg/fed) to the change in independent variables. The variables included in the model were found to be significant at different levels as illustrated in Table (12).

Table (12): **Factors affecting alfalfa crop production-regression equation results in El-Zeidab scheme**

Variables	Coefficients	Standard errors	t-values	Level of Significant (*)
Intercept	28.931	6.065	4,770	**
Average age of tenants	-1.589	0.570	-4.660	**
Family labours (man-day/fed)	-0.453	0.372	-2.409	**
Family size	0.688	0.530	3.321	*
Total farm area (fed)	0.910	0.876	3.086	*
Distance of farm to irrigation source (km)	-0.642	0.048	-3.448	*
Alfalfa area (fed)	-1.235	0.510	-4.299	**
Citrus area (fed)	0.456	0.046	2.251	*
Alfalfa seed rate (kg/fed)	-0.511	0.053	-4.231	**
No. of watering (season)	-1.147	0.097	-2.608	*
Irrigation interval (day)	-0.846	0.190	-2.031	*

Source: Computed from the field survey data (RNS)

R-square = 0.86, Adjusted R-square = 0.68, F-value = 4.638

* = Significant at 90% level of probability, ** = Significant at 95% level of probability, and *** = Significant at 99% level of probability.

From Table (12) the age of tenants has got coefficient of -1.589 indicating a one percent increase on tenants' age will decrease the yield by 1.6%, while the increase in the number of family labour gave a relative increase of 1 % while an increase in family labour will cause a relative decrease of 0.453% in yield of alfalfa. The coefficient of farm area per fed variable has got a positive sign which means a relative yield increase of 0.910% in the yield of alfalfa and the coefficient for the distance of source of irrigation to a farm recorded -0.642 indicating a decrease in yield by 0.6%. The number of watering (per season) variable for alfalfa reflects that a relative increase of 1 % in number of irrigations will cause a relative yield decrease of 1.147%. The change in alfalfa area variable in feddans showed a negative coefficient indicating a decrease in alfalfa productivity by 1.235%. The citruses area variable showed that it's a relative area increase by 1 % will cause a relative increase of 0.456% in the yield of alfalfa. The amount of seed rate (kg/fed) has got a negative coefficient indicating a decrease in alfalfa productivity by 0.511 %. Similarly, the irrigation interval for alfalfa in days was associated with a negative coefficient indicating a decrease in alfalfa productivity by 0.846 %. It can be drawn from the regression analysis that the included variables (Table 12) are the main factors affecting alfalfa productivity and can provide a reliable indicator to assess alfalfa production among the crop combination in River Nile State.

Assessment of resources use for wheat and alfalfa production

Availability of agricultural resources, especially land and irrigation water form essential preconditions for successful agricultural investment in different cash, food products and their commercialization. The long history of an experience in perennials and annual crop production in the country have provided a broad and strong background for Sudanese farmers to manage their farming system to produce various food and cash crops. The combination of annual crops and

livestock herding offers promising options for promoting the farming system and improving livelihoods of rural people. Yet, the high competition for fresh water and fertile land increases the complexity of natural resource use and management. The high cost of production coupled with low productivity and lack of a cheap source of power has made it difficult for farmers to realize the full potential of the region. In fact, agricultural resources are available for increasing agricultural production and raising the living standards of the rural poor. Generally, in River Nile State crop productivity potential within the agricultural sector come from the irrigated sub-sector. Then the important question here is how to balance the use of available agricultural resources in the area of study. Thus, agricultural resource-use efficiency might be an appropriate indicator to build on within the existing circumstances.

Alfalfa and optimal cropping pattern and returns in RNS

This research provides information and results on the objective function value under optimal crop combination and resources used accompanied by their respective marginal value productivities. The actual and optimal cultivated land for the dominant perennial crops combination is presented in Table (13). From the table, the optimal solution reflects devoting land only for alfalfa (at 5 fed), while the rest of the crops including fruits didn't appear in the optimal plan. Thus, policy makers should design the right policies that include how to maximize the available resources. The actual returns from crops production amounted to SD 134998 compared to SD 255215 under the optimal solution; an increase of 89%. The last decades witnessed increased interest to grow perennial crops overall the RNS as well as Northern State, and that might be due to their higher prices and/or the low operation costs when compared to the annual crops according to their time occupation of land. In fact, the higher prices for perennial crops have provided incentives and justifications to grow them. Moreover, growing of perennial crops allows their intercropping by some crops particularly alfalfa according to the mentioned characteristics of the perennials, the resources use and availability might be under competition. The actual and optimal levels of the resources depicted in Table (13) reflect that 50% of the available land should be used for alfalfa apparently due to its high returns compared to other perennial crops.

Table (13): Resources use and cropping pattern plan for Alfalfa in RNS

Item	Actual	Optimal	Units
Resources use:			
Total land	10	5	Fed
Total irrigation water	65613.75	45120	Cubic meter
Total labor	101	60	Man-day
Total capital	960108	737760	SDG
Returns: objfn value (Z)	134998	255215	SDG
Cropping pattern:			
Date	1.23	-	Fed
Citrus	5.01	-	Fed
Alfalfa	**1.72**	**5**	**Fed**
Mango	0.75	-	Fed
Guava	1.29	-	Fed

Source: Model results (RNS)

Resources use and constraints for alfalfa crop

The disappearance of the other perennials in the optimal solution raises concerns about the need for efforts, including appropriate policies, to improve their productivity, as justified by research results, and set their market prices right. This is justified by the fore-mentioned advantages of the other perennials (date palm, citruses, mangoes and guava) in people's livelihood and the actual expansion in their areas. On the other hand, the simplified model – due to lack of information – did not capture issues that would have raised the other perennials gross margins such as their by-products and the expected notable value of crops that can actually be grown underneath the trees. Furthermore, the other perennials are associated with low risks of perishability, long storage potential and low transport costs compared with other fruit plantations.

The model also assumes that the demand for alfalfa is highly inelastic and that there are no constraints on its markets.

Wheat and optimal cropping pattern and returns in RNS

As with the case of alfalfa, the model results for wheat-based system comprise the objective function value (returns), the optimal crop combination, and utilized resources accompanied by their respective marginal productivities. The analysis also provided some other relevant results as shown in Table (14). The Table represents the actual and optimal cultivated area for the different field crops and gives also the optimal average area allocation. The optimal solution indicates land occupation only for chickpea and dry bean at 8.62 and 1.38 fed respectively, while the rest of the crops did not appear in the optimal plan. The actual returns from crop production were SDG 399487, while the optimal returns amounted to SD 891597, which is more than the actual returns by about 123%.

Resources use and constraints

The most important season in RNS is winter; hence the farmers pursue the best crop combination to achieve satisfactory returns. According to the importance of the winter season, the resources use and availability might be described as fully utilized during this season. Norton and Hazell (1986) reported that, introducing seasonality in the model would further restrict the model solution and will likely lead to lower value of the objective function. The actual and optimal levels of the resources are depicted in Table **(**14) per season; the total optimal area is 10 fed, i.e. all available land would be used. It is clear that the optimal plan resulted in all available land to be devoted to chickpea and dry bean due to their high returns when compared to other seasonal crops.

From Table (14) the optimal and actual resources used are illustrated. The Table also depicts the optimal amount of resources used for the different annual crops in the area of study. It reflects that the utilization of agricultural resources for producing the mentioned crop combination increased from October till January the same period of growing winter crops in area of the study. This situation revealed that the period from October to January is considered as the most demanding period that coincides with the growing of winter food and cash crops in northern region of Sudan.

Table (14): **Optimal resources use and cropping pattern plan for El Zeidab scheme tenancy**

Item	Actual	Optimal	Units
Resources use:			
Total land	10	10	Feddan
Total irrigation water	28573	15384.42	Cubic meter
Total labour	191	124	Man-day
Total capital	179532	122236.61	SDG
Returns: objfn value (Z)	399487.28	891596.73	SDG
Cropping pattern:			
Wheat	1.1	-	Fed
Faba bean	1.1	-	Fed
Chick pea	0.3	8.62	Fed
Dry bean	0.6	1.38	Fed
Onions	0.6	-	Fed
Spices	0.9	-	Fed
Vegetables	0.8	-	Fed
Sorghum	1.7	-	Fed
Maize	0.7	-	Fed
Potato	0.4	-	Fed
Fodder	1.8	-	Fed

Source: Model results, 2008

Conclusion and policy implications

This research presents some of the findings of the field survey for public and private schemes surveyed in the RNS of the Northern Region, describing the alfalfa/wheat competitiveness in RNS farming systems and emphasizes the importance of agricultural resources for producing main food and cash crops Conclusion that can be drawn from numerous analytical tools are:

1. Wheat is still a fairly dominant crop and strong competitor in the prevalent crop combination in the River Nile State of north Sudan. In the conventional sub-sector represented by El-Zeidab scheme, wheat ranked after onions by occupying the second highest percentage of land over all the area of the public irrigated schemes. In the modern sub-sector such as Al-Rajhi-Kafaa scheme on the other hand, the allocation of field crops in the scheme was recorded 40% of the total cultivated land occupied by wheat, followed by 30% for all alfalfa, while 20% and 8% were under maize and sunflower, respectively.
2. Alfalfa legume is considered as one of the main competitors in the dominant crop combination of the modern investment and private schemes in RNS. The findings of the study indicate that alfalfa and other fodders had higher opportunity to occupy the available agricultural land within field crops and farming systems in the RNS in particular and the Northern Region in general compared to cereal crops including wheat. The higher annual alfalfa yield and returns resulted in the higher total cultivated areas in absolute and relative terms occupied by alfalfa in the RNS' farming systems and suggest that alfalfa

would be the superior dominant crop enjoying greater competitiveness within the field crop combination in the State.

3. Although wheat is not as profitable as alfalfa, it is enjoying large cultivated areas in the RNS. This due to it is importance as one of the main strategic crops in the country where the national policies usually encourage wheat growers to extend its areas compared to other crops. This also clarifies why most of the cultivated area was covered by cereal strategic crops despite that they are described as very exhaustive crops to the soil fertility. Legumes and vegetable crops formed a limited acreage in the Northern Region. Generally, the crop combination in the state is mainly determined by the nature of season, tenants' experiences, market conditions and others, but in case of wheat its production is mostly determined by national and state agricultural policies.
4. Thus, it is evident that alfalfa fodder crop has ability to utilize and absorb more agricultural resources than wheat due to its importance in the farming system's sustainability. In other words, the yearly increase in alfalfa areas and returns contributed significantly to the increase in annual farm investment and improves the stability of agricultural production.
5. The study revealed that the performance of resources management for agricultural production in the state is bound with low efficiency as reflected in area gaps between the estimated optimal areas that can be cultivated and the actual cultivated areas.

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Research paper

Effect of Various Potting Media on Growth of Geranium Aralia (*Polyscias guilfoylei*)

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Abstract

The objective of the experiment was to study the effect of mixing silty soil (SS) with compost and leaf mould at different ratios on growth of *Polyscias guilfoylei*. Transplants were potted into polyethylene bags containing the following media: silty soil (SS), SS + compost (2 : 1), SS + compost (1 : 2), SS + compost (1: 1), SS + leaf mould (2 : 1), SS + leaf mould (1 : 2), SS + leaf mould (1 : 1). Data were collected on Plant height, number of leaves per plant, number of branches per plant, plant fresh and dry weights. Results revealed that the highest values of plant height, plant fresh and dry weights were associated with silty soil (SS). The highest values of number of leaves per plant was associated with SS + compost (1 : 1) and number of branches per plant with SS + compost (1 : 1) and (1 : 2).

Keywords: Polyscias guilfoylei, potting media, compost, leaf mould, growth.

تأثير أوساط تعبئة مختلفة على نمو نبات (*Polyscias guilfoylei*) Geranium Aralia

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المستخلص

الهدف من التجربة اختبار تأثير خلط التربة السلتية (ت. س) مع الكمبوست والأوراق المتحللة بنسب مختلفة على نمو نبات ال (*Polyscias guilfoylei*) Geranium Aralia. زرعت الشتلات في اكياس بلاستيك محتوية على الاوساط التالية: تربة سلتية، ت. س + كمبوست (2 : 1)، ت. س + كمبوست (2:1)، ت. س + كمبوست (1:1)، ت. س + أوراق متحللة (2 : 1)، ت. س + أوراق متحللة (2:1)، ، ت. س + أوراق متحللة (1:1). جمعت البيانات حول ارتفاع النبات، عدد الأوراق بالنبات، عدد الأفرع بالنبات، الوزن الطازج والوزن الجاف للنبات. أظهرت النتائج أن أعلى قيم لارتفاع النبات، وزن النبات الرطب والوزن الجاف تم الحصول عليها عند استخدام التربة السلتية (ت. س). أعلي قيم لعدد الأوراق بالنبات تم الحصول عليها عند استخدام ت. س + كمبوست (1:1) وعدد الأفرع بالنبات تم الحصول عليها عند استخدام ت. س + كمبوست (1:1) و (1:2).

كلمات مفتاحية: الاراليا، أوساط التعبئة، كمبوست، أوراق متحللة، النمو.

Introduction

Polyscias guilfoylei commonly known as coffee tree or Geranium Aralia belonging to family Araliaceae is a tropical plant native to southeast Asia. The showy leaves are often variegated with white or yellow margins or they can be all green. It is suitable for growing indoors as a houseplant, and it can be used as a bonsai specimen. It requires well-drained loamy acidic (pH<6.0) potting soil high in organic matter (Anonymous, 2020). In nursery production industry, a variety of growing media are in use worldwide, especially in the ornamental plant production. Growing media are an integral part of most horticultural production systems. There is a wide range of media available. Growing media are the substrates in which a plant will grow. They provide anchorage for the plant's roots; air spaces to allow respiration; and retain sufficient available water to enable plant growth. Potting soil mixes are the most important factors for the quality production of plants. Correct combination of substrates for growing media to optimize plant growth is demanding and represents about 4-6% of the cost of production for bedding plants (Khan *et al*., 2012). Organic materials from agriculture, forestry, green areas, and livestock farming as well as residues from municipal and industrial waste are rich sources of different nutrients (Fitzpatrick, 1986) and all have been strongly recommended for use as renewable

resources in pot production, an effort that would help to palliate their harmful impact on local and global environmental degradation (Ribeiro *et al*., 2007). The positive effects of organic amendments could be attributed to their effects in supplying the treated plants with their requirements of nutrients for relatively long time as well as their effects in lowering soil pH which could aid in facilitating availability of soil nutrients and improve physical characters in favour of roots development (Gamal and Ragab, 2005). The container medium for raising ornamental plants in most nurseries in the Sudan is the silty soil. Recently some nurseries have started using some imported potting media. Research on using potting media is very meager in Sudan. The objective of the experiment was to study the effect of mixing silty soil with compost and leaf mould at different ratios on growth of *Polyscias guilfoylei*.

Materials and methods

This study was conducted at the ornamental plants nursery of the Department of Horticulture, Faculty of Agriculture, University of Khartoum, Sudan, during the year 2013. *Polyscias guilfoylei* transplants were potted into polyethylene bags containing the following media: silty soil (SS), SS + compost (2 : 1), SS + compost (1: 2), SS + compost (1 : 1), SS + leaf mould (2 : 1), SS + leaf mould (1 : 2), SS + leaf mould (1 : 1). Leaf mould was mango leaves buried in the ground for tens of years under trees growing at the mango orchard of the Department of Horticulture. The compost was prepared by the Department of Soil and Environmental Sciences, Faculty of Agriculture, University of Khartoum. Some properties of the silty soil, compost and leaf mould which were determined at the laboratory of the same department, are shown in Table 1. A randomized complete block design was used. Three plants represented an experimental unit. Each experimental unit was replicated four times. Statistical analysis was carried out using the SPSS program (version 20/ 2014) and means were compared for significance by using Duncan's multiple range tests at 5% level of significance. Data were collected on Plant height, number of leaves per plant, number of branches per plant, plant fresh and dry weights.

Table (1): Some properties of silty soil, compost and leaf mould

Potting mix	pH	ECe ds/m	Ca meq/l	Mg meq/l	Na meq/l	K meq/l	SAR	N %	P Ppm
Silty soil	7.8	1.1	2.1	5.8	1.8	0.26	1.0	0.04	6.0
Compost	6.7	2.4	17.0	21.0	84.6	105.0	19.0	0.30	34.0
Leaf mould	7.9	4.19	9.9	7.2	24.8	0.40	8.0	0.59	15.0

Results and discussion

Excluding silty soil treatment, there was no significant difference in plant height among the rest of the treatments. Silty soil (SS) treatment resulted in the highest plant height differing significantly ($P \leq 0.05$) from all SS + leaf mould treatments (Table 2). Plant fresh weight was also significantly ($P \leq 0.05$) higher with Silty soil treatment compared to the rest of the treatments among which there was no significant difference (table 3). As shown in table 3 the highest plant dry weight (0.526 g) was also recorded by silty soil treatment with significant difference ($P \leq 0.05$) from the treatments SS + leaf mould (2 : 1) and SS + leaf mould (1 : 2). Results of plant height, plant fresh and dry weights are in agreement with those of Ahmad (1997) who studied the effect of five different soil mixes namely silty soil, SS + sand (2:1), SS + compost (2:1), SS + compost (1:2) and SS + compost (1:1) on growth of white Ixora, *Acalypha* and *Pedilanthus* plants and found highest plant height, plant fresh and dry weights associated with silty soil. Although the difference in number of leaves per plant and number of branches per plant among treatments was not significant, the treatment SS + compost (1:1) recorded highest values of these two parameters (Table 2). This result is comparable with that of Ahmad and Qasim (2003) who studied the effect of various potting media on growth response and nutrient uptake efficiency of *Scindapsus aureus* using farm yard manure, leaf mold, poultry manure in different combinations with sand, silt and saw-dust. Potting media in different combinations were better than sole one; as they revealed more growth and vigor. Riyaz *et al*. (2008) found no significant differences in number of leaves per plant between silty soil alone and silty soil amended with leaf manure and coconut compost in *Zinnia elegans*. However, silty soil amended with leaf manure and coconut compost resulted in significantly higher number of branches per plant than silty soil alone. Many research workers reported positive effects of organic amendments on growth of different plants (Nethra *et al*., 1999 in *Callistephus chinensis*, Khayyat *et al.*, 2007 in *Epipremnum aureum*, Kiran *et al*., 2007 in *Dahlia pinnata*, Gupta *et al*., 2014 in marigold, Riyaz *et al*., 2015 in *Gerbera jamesonii*, Ravishankar *et al.*, 2004 in papaya and Mumtaz *et al.*, 2006 in rough lemon). Depending on cost of media, silty soil or the mixture SS + compost (1:1) can be regarded as suitable potting media for *Polyscias guilfoylei*.

Table (2): Effect of different potting mixes on growth parameters of *Polyscias guilfoylei* twenty eight weeks after transplanting.

Potting Mix	Plant height (cm)	Number of branches/plant	Number of leaves/plant
Silty soil (SS)	76.33b	2.50a	35.50a
SS + compost (2:1)	66.00ab	2.50a	39.75a
SS + compost (1:2)	71.00ab	3.00a	43.25a
SS + compost (1:1)	68.75ab	3.00a	48.00a
SS + leaf mould (2:1)	63.25a	2.50a	35.75a
SS + leaf mould (1:2)	61.25a	2.50a	38.75a
SS + leaf mould (1:1)	64.42a	2.00a	46.00a

Means followed by the same letter/s in a column are not significantly different (P = 0.05) according to Duncan's Multiple Range Test.

Table (3): Effect of different potting mixes on growth parameters (fresh and dry weights) of *Polyscias guilfoylei* twenty eight weeks after transplanting.

Potting Mix	Plant fresh weight (g)	Plant dry weight (g)
Silty soil (SS)	0.732c	0.526b
SS + compost (2:1)	0.257ab	0.247ab
SS + compost (1:2)	0.470b	0.450b
SS + compost (1:1)	0.402b	0.355ab
SS + leaf mould (2:1)	0.258ab	0.217a
SS + leaf mould (1:2)	0.385ab	0.148a
SS + leaf mould (1:1)	0.252ab	0.249ab

Means followed by the same letter/s in a column are not significantly different (P = 0.05) according to Duncan's Multiple Range Test.

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Research paper

One Step in vitro Propagation and Production of Potato *(Solanum tuberosum L.)* Minitubers Using Different Concentrations of Indole-3-acetic acid and Kinetin

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Abstract

This study was carried out to evaluate the effect of different concentrations of the growth regulators Indole-3-acetic acid (IAA) and Kinetin on *in vitro* shoot regeneration and rooting in one step using nodal explants of Zafera and Mondial potato varieties widely grown in Sudan for the ultimate aim of producing minitubers. The two growth regulators resulted in regeneration of healthy shoots and roots in one step and produced minitubers from acclimatized plantlets. Plant height, shoot number and leaves number were positively affected by increasing concentrations of both IAA and kinetin in the two potato varieties used. Number of roots and root length were only positively affected at higher concentration of IAA. Survival percentage of plantlets was not significantly affected by the two growth regulators. Minitubers were successfully produced using acclimatization potting media.

Keywords: Potato, growth regulators, acclimatization, potting media, minitubers.

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اكثار البطاطس وانتاج الدرنات الصغيرة في خطوة واحدة باستخدام تراكيز مختلفة من اندول حمض الخليك والكينتين خارج الجسم الحي

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المستخلص

اجريت هذه الدراسة لتقييم تأثير تراكيز مختلفة من منظمات النمو اندول حمض الخليك والكينتين على تكوين وتجذير الأفرع في خطوة واحدة خارج الجسم الحي باستخدام العقل العقدية لصنفي البطاطس زافيرا ومونديال المزروعة بكثرة في السودان بغرض انتاج الدرنات الصغيرة كهدف نهائي. منظمات النمو نتج عنهما تكوين أفرع وجذور بحالة جيدة في خطوة واحدة. ثم انتاج الدرنات الصغيرة من النباتات الماقلمة. طول النبات، عدد الأفرع وعدد الاوراق تأثرت ايجابيا بزيادة تركيز كلا منظمي النمو. عدد الجذور وطولها تأثراً ايجابياً بزيادة تركيز اندول حمض الخليك فقط. لم تتأثر نسبة بقاء النبيتات حية بتركيزات منظمات النمو المستخدمة. تم انتاج الدرنات الصغيرة بنجاح باستخدام أوساط التعبئة المستخدمة في الأقلمة.

كلمات مفتاحية: البطاطس، منظمات النمو، الأقلمة، أوساط التعبئة، الدرنات الصغيرة.

Introduction

Potato *(Solanum tuberosum* L.) is an important food crop worldwide. Its global production is estimated at 388,191,000 tons in 2017. Area under crop cultivation in Sudan is about 33000 ha producing 425,000 tons which is far below neighboring Egypt with production of about 4,326,000 tons (FAOSTAT, 2019).

There are various problems associated with potato production, among them shortage of high quality seed tubers has been identified as the most limiting factor of potato production in the developing countries, Sudan of course is not an exception. Compared to true seeds, seed tubers have the risk of carrying-over plant pathogens to the new crop. High risk of catching various diseases in open fields (fungal, viral, and bacterial) and vector pests usually cause degeneration of the seed tubers and low productivity if used in subsequent cropping. This is why most countries impose hard rules and standards to seed tuber production.

In Sudan, due to the short growing season, potato seed-tubers are better to be sown early to fit cold temperature conditions of short winter season during growth and tuberization. However, imported high quality tubers can scarcely be fetched in the proper time of planting in early November (Ali and Abdalla, 2010). Rapid multiplication of potato using tissue culture techniques could be a solution. These techniques were developed and widely utilized in potato seed tuber production to provide large quantities of plantlets, minitubers and microtubers. Apical meristem is utilized and subcultured on laboratory prepared culture media to be used as high quality starting material that can be produced year round in *in vitro* conditions. Nodal stem cuttings, in which apical and axillary buds can grow to form a new plant are usually used for mass

production. This can be realized in short periods of three to four weeks. This is, why this technique is widely adopted for quality seed tuber production (Naik and Karihaloo, 2007).

Most of the reported potato tissue culture protocols are genotype-specific. The question then will be how to develop a potato micropropagation protocol that could be effectively used through most desired genotypes and in a single step without dealing with shoot regeneration and rooting in separate steps.

Auxin and cytokinin have contrasting roles in root meristems development as stated by Evans *et al*. (1994) and Dello Ioio *et al*. (2007). Auxin is required for meristem cell division. Application of exogenous auxin usually increases root meristem size, whereas, cytokinin reduces it. Variations in the endogenous levels of plant hormones in these explants my induce differences between varieties.

Healthy production of plantlets is considered as the main objective of potato *in vitro* multiplication. However, malformed growth with rudimentary shoots and rooting structure is largely reported (Kaur *et al*., 2017). Kumlay (2014) concluded that combined effect of various concentrations of NAA, IAA, and IBA plus GA3 was more pronounced compared to an auxin used alone. Generally, a low ratio of auxin to cytokinin is required for adventitious shoot development in case of potato (Anjum and Ali, 2004), while, reasonable number of roots of 5-6 cm is sufficient to transfer plantlets to successful acclimatization.

High percentage of tissue cultured plantlets losses when transferred to *ex vitro* condition is widely reported (Deb and Iachen, 2010). Reasons for losses may be pathogens from unsterilized growing media or inefficient rooting that can compensate water loss from plant by evapotranspiration. This shows why proper acclimatization techniques are usually required.

For proper shoot and root growth, potting media must provide water to plant, supply it with nutrients, permit gas exchange to and from its roots. and provide support for it (Brown, 2018). All media provide plant support, while the nutrients can be provided by fertigation. Water and air are provided in the pore spaces in the acclimatization media.

Factors affecting air and water status within the media are controlled largely by medium physical properties. Each growing media single component has its own desired and undesired properties. For example, sand had good aeration and drainage but poor in providing and withholding water and nutrient due to its large size particles and low cation exchange capacity (CEC). In contrast peat moss and fine particle soils has high CEC, however, fine soil may not improve drainage and air space, depending on the size and shape of the particles. At the same time peat moss, though have high CEC and wettability, it considered poor in nutrients unless added from outside source and have low pH which is not a desirable character.

Sand and peat moss are very loose and having fragile nature and low plasticity. This character can amend undesirable plasticity of mineral clays of Sudanese revarian soils.

Minitubers which can be planted directly in the field, are small tubers of 5–25 mm in diameter and a range in weight between 0.1–10 g and sometime higher. Minitubers can be obtained from

in vitro plantlets after acclimatization and planting them in a soil substrate. Generally, they are produced under *ex vivo* conditions. The number of minitubers can be 2–10 per plantlet and sometimes it can be more, depending on the mother plant management (Otroshy, 2006). This study was carried out to evaluate the effect of the two growth regulators IAA and kinetin at different concentrations on *in vitro* shoot regeneration and rooting in one step of two potato varieties for *ex vitro* production of minitubers during acclimatization in potting media.

Materials and method

Plant materials

Two farmer preferred potato varieties; Zafera and Mondial were selected to examine their micro-propagation performance under selected growth regulators combinations in the tissue culture laboratory of the Faculty of Agriculture, Nile Valley University, Darmali, Sudan. Tubers were fetched from seed tuber importers, cleaned sterilized and treated with 0.1 mg/L of Gibberellin (GA_3) for half an hour to break dormancy and enhancing sprouting. One mm of shoot tip was taken as initial explant. After realization of reasonable growth size, nodal cuttings were used for further experimentation.

Sterilization and media preparation techniques

Full strength Murashige and Skoog (1962) medium (MS) was used by preparing one working liter from stock solutions adapted from Nasr El-din *et al*. (2014). Addition of growth regulators and vitamins were made according to their heat stability, before autoclaving. Then 30 g sucrose and 7g of agar added and heated on hot plate after adjusting pH to 5.8 till full blend. Media containing jars were autoclaved to about $121C^0$ for about 15-20 minute till pressure in the autoclave reached 15 psi. Jars were then taken to settle overnight in the incubation room before used for sub culturing.

Sterilization of the shoot tips and nodal cuttings was carried out using 70% ethanol by dipping for 30 sec. with a subsequent sterilization using 5% Clorox for 20 minutes. Final sterilization was done using 0.1% $HgCl_2$ (Mercuric chloride) solution for 3 minutes. Sterilized distilled water was finally used for through washing.

Explants were incubated in the incubation room at 24±2°C and 16/8 light/dark photoperiod for about four weeks, during which developed plantlets were examined for various growth parameters.

In the tissue culture media, the two growth regulators used were IAA and kinetin each with three concentrations (0.1, 0.2 and 0.4 mg/l.). Statistically growth regulators concentration levels were arranged in factorial randomized complete block replicated four times with three IAA concentration and three concentration of kinetin. One explant as 2-3cm nodal cutting transferred to each container. Parameters measured were; plant height(cm), shoot No., leaves No., root No., root length (cm) and survival percentage. ANOVA and means differences were analyzed by LSD using SAS statistical computer programme (2003).

Acclimatization experiments and tuberization

The plants roots washed with distill water to clean the agar and the media. Then the roots were dibbed in fungicide to prevent fungal infection. plants were then transferred to acclimatization pots containing many types of growing mixes (comprising some or all of sterilized sand, beat moss, clay); sand, beat and clay (1:1:1). sand and beat (1:1), sand alone and beat alone. The acclimatization pots with plant covered with polyethylene bags to retain adequate humidity around plantlets for two weeks within which the polyethylene bags perforated till the plant discovered completely, then plants transferred into large pots for tuberization in nursery.

Primary acclimatization experiment was statistically analyzed using randomized complete block design with three replications. ANOVA and means differences were analyzed by LSD using SAS statistical computer programme (2003). Plant height, leaves number, shoot number and plant growth strength were parameter taken. Finally, after tuberization, number of tubers, size of tubers, weight of tubers was measured and categorized into four weight and four size groups (5-14,15-24,25-34 and 35-45grams by weight and 5- 15,16-26,27-37 and 38-48 cm^3 by size).

Results and discussion

Main effect of indole-3-acetic acid (IAA)

Results revealed significant differences in plant length with Zafera variety under different concentrations of the auxin (IAA) as shown in Table (1). Highest plantlets obtained when the auxin concentrations were 0.4and 0.2 mg/L (12.25 and 11.33 cm) and the lowest when the concentration of the auxin was 0.1 mg/L (8.79 cm). the result obtained accord with that of Hoque, (2010) in concentrations of 0.2 mg/L of IAA and Kin. Mean shoot No. was significantly affected by different concentrations of auxin (IAA) only with Mondial variety (Table 2). Highest shoot number obtained when the auxin concentrations was 0.2 mg/L (5.58) and the lowest when the concentration of the auxin was 0.1 mg/L (4.42).

With regard to number of leaves; effect was significant with Zafera variety. Highest number of leaves (24.83) were recorded when auxin concentration was 0.4 mg/L and least numbers (20.00) when the concentration was 0.1mg/L.

Auxin concentrations affected significantly root numbers and roots length in both varieties. The highest number of roots obtained when the auxin concentration was 0.4 mg/L (15.08 for Zafera and 11.33 for Mondial) and the lowest obtained when concentration was 0.1 mg/L (10.08 for Zafera and 7.75 for Mondial).

Several researchers indicted that the longest roots were grown on IAA containing medium (Haque, 2010; Bhuiyan, 2013; Dhaka and Nailwal, 2015). In this study, highest number of roots recorded when the auxin concentration was 0.4 mg/L (16.50 cm for Zafera and for 13.75 cm for Mondial) and the lowest number was 8.5 cm recorded with Mondial when auxin concentration was 0.1mg/L result agree with that obtained by Hoque. (2010) who reported maximum number of roots (17.4) using 0.25 mg/L IAA, Bhuiyan (2013) when used 0.5 mg/L IAA and Dhaka and Nailwal (2015) using 2.45 μM IBA.

Genotypic differences, as detected between the two varieties, in their response to different concentration of auxins on rooting behavior were examined by various workers (Pereira and Fortes, 2003; Al-Sulaiman, 2011; Moeini *et al*., 2011 and Chaudhary and Mittal, 2014)Kolachevskaya *et al*. (2019) reported that potato growth, development and morphogenesis are under hormonal control, but the species-specific features in such regard should not be underestimated.

No significant differences were shown by the two varieties as affected by auxin concentration, however, hundred % survival rates were obtained in all concentrations.

Main effect of Kinetin

Results revealed significant differences in plant length with both varieties under different concentrations of kinetin. Highest plantlets obtained when kinetin concentrations were 0.4 and 0.2 mg/L (11.83 and 11.33 cm, respectively for Zafera and 10.45 and 10.13 cm, respectively for Mondial) and the lowest when the concentration of kinetin was 0.1 mg/L (9.21 and 7.71 cm for Zafera and Mondial, respectively). Results were in harmony with that of Kumlay (2018) and Ercisli (2018), Al-Taleb *et al*. (2011) and Fite *et al*. (2003) and were not in line with that of Ibrahim *et al*. (2016) who found no significant difference in plant length of two cultivars (Santana and Innovator) under different MS salt strength and Shibli *et al*. (2001) who sub-cultured in vitro shoots of potato cultivar Spunta in liquid MS medium containing 0.0, 0.5, 1.0, 1.5 and 2.0 mg/l benzyl adenine (BA) or kinetin and observed a significant reduction in stem and internodal length by increasing BA and kinetin concentration in MS medium. Sota *et al*. (2020) also noticed higher concentrations of BAP or kinetin (1 mg/L) caused decrease in biometric parameters except leaves number and they observed slight efficiency of kinetin in comparison to BAP.

Significant differences were also observed with number of shoots on both varieties. The highest number of shoots recorded when kinetin conc. was 0.4 mg/L (5.17 and 6.17 for Zafera and Mondial respectively). The lowest shoots number obtained from the low kinetin (3.58 shoots for both varieties). These results are in line with the findings of Rahimian *et al*. (2019).

Increasing kinetin concentrations increased significantly leaves number. The highest number of leaves was obtained from 0.4 mg/L in both varieties (26.76 for Zafera and 23.33 for Mondial). The lowest leaves number was recorded by low kinetin concentration (21.25 with Zafera and 18.17 with Mondial). Sota *et al*. (2020) obtained similar results.

Table (2) show that there is no significant effect for concentration of kinetin in both of root number and survival rate for both varieties.

Interaction effect of growth regulators

As shown in Table (3) different concentrations of IAA and kinetin affected variably shoot length. The effects were not significant for Mondial, However, for Zafera significant interactive effect were noticed with hormonal combination of 0.2 IAA+ 0.2 KIN, 0.2 IAA+ 0.4 KIN, 0.4 IAA+ 0.2 KIN and 0.4 IAA+ 0.4 KIN. The longest shoots were obtained from 0.4 IAA+ 0.4 KIN (14 cm).

Regarding shoot number. significant interactive effects were noticed with Mondial only. Hormonal combinations affected shoot number were; 0.1 IAA+ 0.2 KIN, 0.1 IAA+ 0.4 KIN, 0.2 IAA+ 0.2 KIN, 0.2 IAA+ 0.4 KIN, 0.4 IAA+ 0.2 KIN, 0.4 IAA+ 0.4 KIN. Highest shoot numbers were noticed with 0.2 IAA+ 0.4 KIN hormonal combinations (6.75).

Hormonal combinations showed significant interaction effects on leaves number with Zafera were 0.1 IAA+ 0.4 KIN,0.2 IAA+ 0.1 KIN,0.2 IAA+ 0.2 KIN,0.2 IAA+ 0.4 KIN,0.4 IAA+ 0.2 KIN and 0.4 IAA+ 0.4 KIN. However, only .4 IAA+ 0.2 KIN and 0.4 IAA+ 0.4 KIN showed significant effect with Mondial. Highest leaves numbers were recorded by the highest combination 0.4 IAA+ 0.4 KIN (29 and 26 leaves for Zafera and Mondial, respectively).

Hormonal combinations**;** 0.2 IAA+ 0.1 KIN,0.2 IAA+ 0.2 KIN,0.2 IAA+ 0.4 KIN,0.4 IAA+ 0.1 KIN,0.4 IAA+ 0.2 KIN and 0.4 IAA+ 0.4 KIN showed significant interactive effects on both root number and root length (cm) with the two varieties. The highest root number for Zafera(15.75) recorded by the hormonal combination (0.2 IAA+ 0.4 KIN), while for Mondial (12.25) recorded by the hormonal combination (0.4 IAA+ 0.4 KIN). Highest root length for both varieties were recorded by the hormonal combination; 0.4 IAA+ 0.1 KIN and 0.2 IAA+ 0.4 KIN. (16.75 for Zafera and 14.25 for Mondial).

Survival rate showed no interactive effect due to different hormonal combination.

Acclimatization results and Minitubers production

As shown in Table (4), significant effect was noticed from different growing mixes on plant length (p=0.0119). The highest plant length obtained from peat, sand and silt mix and sand only in both varieties (24.00 and 23.33 cm with Zafera and 17.33,19.33 cm with Mondial for peat, sand and silt mix and sand only respectively). The lowest values were obtained from peat only and peat and sand mix (18.67 cm with Zafera and 13.67cm with Mondial).

Leaf number was significantly affected due to different acclimatization potting media (p<.0001). The highest number of leaves (28.67 for Zafera and 24.33 for Mondial) were obtained when peat + sand + silt was used and the least values in Zafera when peat only used (15) and in sand for Mondial (18).

Shoot number showed high significant effect (P=0.0005) as affected by potting mix in both varieties. The highest shoot number (7.33 for Mondial and 6 for Zafera) were recorded in peat + sand +silt. The lowest numbers of shoot (1.33 for Zafera and 2.33 for Mondial) were recorded when sand only was used. Similar results on sand and silt was reported by Dessoky *et al*. (2016).

Regarding growth strength, though plants of peat + sand +silt showed good growth strength, the effects were not statistically significant.

Mean tuber number per plant as presented in Table (5) showed that Mondial produced about 16 and Zafera 13 mini tubers with different weights and sizes on peat + sand +silt mix 115 days after replanting and half of the period outside the incubation room under insect proof net in the nursery. Mondial produced also tubers of larger sizes and weight compared to Zafera. Results

obtained was in line with that of Moeini *et al*. (2011) with regard to in size and weight obtained by different mixes and varieties. They produced mini-tubers only in peat moss/sand while other potting mixes did not produce any tuber.

Conclusion

Indole acetic acid and kinetin could be used successfully as individual source of auxin and cytokinin, for healthy shoot and root regeneration in one step from nodal potato explants. Potato mini-tubers produced successfully on peat moss, sand and clay (1:1:1) potting mix.

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Table (1): Main effect of different IAA concentrations used with three Kinetin concentrations on growth of in vitro cultures of Zafera and Mondial potato varieties four weeks after culture.

Conc. (mg/l)	Plant height (cm)		Shoot No.		Leaves No.		Root No.		Root length (cm)		Survival percentage	
	Zafera	Mondial	Zafera	Mondial	Zafera	Mondial	Zafera	Mondial	Zafera	Mondial	Zafera	Mondial
0.1 IAA	8.79 b	9.50a	4.42 a	4.42b	20.00 b	19.67a	10.08 b	7.75b	9.08 b	8.50 c	100 a	100 a
0.2 IAA	11.33 a	9.17a	4.33 a	5.58a	24.83 a	20.25a	14.17 a	10.33a	15.58 a	11.75b	90 a	100 a
0.4 IAA	12.25 a	9.63a	4.75 a	5.00ab	24.75 a	22.58a	15.08 a	11.33a	16.50 a	13.75a	100 a	100 a
	***	NS	NS	**	***	NS	***	***	***	***	NS	NS

Means within column with the same letter are not significantly different at indicated confidence level

Table (2): Main effect of different Kinetin concentrations used with three IAA concentrations on growth of *in vitro* cultures of Zafera and Mondial potato varieties four weeks after culture.

Conc. (mg/l)	Plant height (cm)		Shoot No.		Leaves No.		Root No.		Root length (cm)		Survival percentage	
	Zafera	Mondial	Zafera	Mondial	Zafera	Mondial	Zafera	Mondial	Zafera	Mondial	Zafera	Mondial
0.1 Kinetin	9.21 b	7.71b	3.58 b	3.58c	21.25 b	18.17b	13.00 a	9.08b	13.42 a	11.83a	100 a	100 a
0.2 Kinetin	11.33 a	10.13a	4.75 a	5.25b	21.67 b	21.00a	12.92 a	9.75b	14.08 a	11.17a	90 b	100 a
0.4 Kinetin	11.83 a	10.45a	5.17 a	6.17a	26.67 a	23.33a	13.42 a	10.58a	13.67 a	11.00a	100 a	100 a
	***	**	***	***	***	**	NS	**	NS	NS	*	NS

Means within column with the same letter are not significantly different at indicated confidence level

Table (3): Interaction effect of different hormonal concentration on growth of tissue culture potato nodal plantlets of Zafera and Mondiaal varieties

IAA+ KIN conc. (mg/l)	Plant height (cm)		Shoot No.		Leaves No.		Root No.		Root length (cm)		Survival percentage	
	Zafera	Mondial	Zafera	Mondial	Zafera	Mondial	Zafera	Mondial	Zafera	Mondial	Zafera	Mondial
0.1 IAA+ 0.1 KIN	7.625	7.88	4.25	3.25	19	19.25	10	6.25	8.75	8.75	100	100
0.1 IAA+ 0.2 KIN	9.75	10.38	4.5	4.75*	17.75	17.75	10	8	9.5	8.25	100	100
0.1 IAA+ 0.4 KIN	9	10.25	4.5	5.25**	23.25*	22	10.25	9	9	8.5	100	100
0.2 IAA+ 0.1 KIN	9.5	7.38	3	4.25	23.25*	18.5	15**	10***	14.75***	12.5*	100	100
0.2 IAA+ 0.2 KIN	12**	10.5	4.75	5.75***	23.5*	20.5	13*	10.5***	16***	11*	70	100
0.2 IAA+ 0.4 KIN	12.5**	9.63	5.25	6.75***	27.75***	21.75	14.5*	10.5***	16***	11.75**	100	100
0.4 IAA+ 0.1 KIN	10.5	7.88	3.5	3.25	21.5	16.75	14**	11***	16.75***	14.25***	100	100
0.4 IAA+ 0.2 KIN	12.25***	9.5	5	5.25***	23.75*	24.75*	15.75***	10.75***	16.75***	14.25***	100	100
0.4 IAA+ 0.4 KIN	14***	11.5	5.75	6.5***	29***	26.25*	15.5***	12.25***	16***	12.75***	100	100

Table (4): Effect of various potting media on growth of plantlets of Zafera and Mondial potato varieties 15 days after beginning of primary acclimatization

Acc. Media	Plant height (cm)		Leaves No		Shoot No		Plant growth strength	
	Zafera	Mondial	Zafera	Mondial	Zafera	Mondial	Zafera	Mondial
Peat +sand+ silt	24.00	17.33	24.00	17.33	6.00	7.33	5	5
Sand+peat	19.00	13.67	19.00	13.67	3.67	7.00	3	4
Peat	18.67	15.67	18.67	15.67	2.33	5.33	2	2
Sand	23.33	19.33	23.33	19.33	1.33	2.33	4	3
CV %	14.39		12.52		35.80		0	
P media	0.0119		<.0001		0.0005		NS	
P variety	0.0006		NS		0.004		NS	
P M X V	NS		0.0121		NS		NS	
LSD M	3.32		3.16		1.94			
LSD V	2.35		2.24		1.37			

Table (5): Mean tubers numbers per acclimatized plants according to weight (g) and size (cm^2)

Variety	Mean tubers numbers per plant according to weight (g)				Total /plant	Mean tubers numbers per plant according to size (cm^2)				Total /plant
	5-14	15-24	25-34	35-45		5-15	16- 26	27-37	38-48	
Mondial	3.33	4.00	4.33	4.66	16.33	3.66	3.66	4.33	4.66	16.33
Zafera	6.00	5.33	1.66	0.00	13.00	6.66	4.66	1.66	0.00	13.00

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Research paper

Micropropagation of Gerbera (*Gerbera jamesonii* Bollus) Using Capitulum Explants

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Abstract

Three separate experiments were conducted to study the effect of the cytokine benzyl amino purine (BAP) concentration (0, 2, 4, 6 and 10 mg l^{-1}) and medium status (solid with agar versus liquid with cotton support); number of capitulum sections (2, 4, 8, 16 sections) on *in vitro* shoot regeneration on capitulum explants of the gerbera cultivar "Evergreen" and indole-3-butyric acid (IBA) concentration (0, 0.5, 1, 2 mg l^{-1}) on *in vitro* rooting of shoots using half MS salt strength. Data were collected on percentage of responding explants, number of shoots/explant, rooting percentage, number of roots per shoot and root length. The highest percentage of responding explants (86.6 %) and highest number of shoots/explant (4.77 shoots) were recorded by the solid medium supplemented with 4 mg l^{-1} BAP. The solid medium gave significantly higher number of shoots/explant (2.37) than the liquid one (1.53). There was no shoot formation in BAP- free medium. Cutting the capitulum into 8 sections resulted in the highest percentage (76.6%) of responding explants and highest number of shoots per explant (6.55 shoots). There was no significant difference between treatments in percentage of rooted shoots. The highest rooting percentage (86.6%) resulted from the treatment 2 mg l^{-1} IBA and the lowest one (66.6 %) was given by the control. The treatment 2 mg l^{-1} IBA resulted in, significantly, the highest number of roots per shoot (8.8) and the lowest number of roots (2.1) was given by the control. There was no significant difference between treatments in root length. The treatment 0.5 mgl^{-1} IBA gave the highest root length (20.7 mm). The lowest root length (12.2 mm) was given by the control.

Keywords: Micropropagation, *Gerbera jamesonii*, Capitulum explants, benzylaminopurine, Indole butyric acid, *In vitro* rooting.

الإكثار الدقيق للجيربرا (*Gerbera jamesonii* Bollus) باستخدام البراعم الزهرية كأجزاء نباتية منفصلة

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المستخلص

أجريت ثلاث تجارب منفصلة لدراسة تأثير تركيز السايتوكاينين بنزيل أمينو بيورينBAP (0،2، 4، 6، 10 ملجم/ لتر) و حالة الوسط الغذائي (صلب باستخدام الأجار مقارنة مع الوسط السائل باستخدام القطن كدعامة)، وعدد قطع البرعم الزهري (2،4،8،16) على تكوين الأفرع على البراعم الزهرية الصغيرة لصنف الجيربرا Evergreen خارج الجسم الحي وتركيز أندول حمض البيوترك IBA (0.0، 0.5، 1.0، 2.0 ملجم/لتر) على تجذير الأفرع خارج الجسم الحي باستخدام نصف تركيز أملاح وسط موراشيجي و اسكوق (MS). جمعت بيانات عن نسبة الأجزاء النباتية المنفصلة التي استجابت وعدد الأفرع بالجزء النباتي المنفصل ونسبة التجذير وعدد الجذور بالفرع وطول الجذر. أعلى نسبة (86.6 %) للأجزاء النباتية المنفصلة التي استجابت و أعلى عدد للأفرع بالجزء النباتي المنفصل (4.77 فرع) فقد سجلت في الوسط الصلب المضاف إليه 4 ملجم/لتر BAP. الوسط الصلب أعطى و بدرجة معنوية أعلى عدد للأفرع بالجزء النباتي المنفصل (2.37 فرع) من الوسط السائل (1.53 فرع). قطع البرعم الزهري إلى 8 أجزاء نتج عنه أعلى نسبة من الأجزاء النباتية المنفصلة التي إستجابت (76.6 %) وأعلى عدد للأفرع بالجزء النباتي المنفصل (6.55 فرع). لم يكن هنالك فرق معنوي بين المعاملات في نسبة التجذير لكن المعاملة 2 ملجم/لتر IBA أعطت أعلى نسبة تجذير (86.6 %) وأقل نسبة تجذير (66.6 %) أعطيت بواسطة الشاهد. المعاملة 2 ملجم/لتر IBA نتج عنها وبدرجة معنوية أعلى عدد للجذور بالفرع (8.8) وأقل عدد للجذور (2.1) أعطي بواسطة الشاهد. الفرق بين المعاملات في طول الجذر لم يكن معنوياً أعطت المعاملة 0.5 ملجم/لتر IBA أطول جذر (20.7 ملم) بينما أعطت معاملة الشاهد أقصر جذر (12.2 ملم).

كلمات مفتاحية: الاكثار الدقيق، الجيربرا، البرعم الزهري كجزء نباتي منفصل، بنزيل أمينو بيورينBAP، اندول حمض البيوترك، التجذير خارج الجسم الحي.

Introduction

Gerbera (*Gerbera jamesonii Bolus*), commonly known as Transvaal Daisy and Barberton Daisy is an important cut flower worldwide. It ranks fifth in the international cut flower trade. Gerbera is ideal for beds, borders, pots and rock garden. The flowers which are of various colors suit very well in different floral arrangements. The cut blooms also have a long vase life of about 7 to 8 days (Van Son, 2007).

Like other ornamental plants gerberas are produced exclusively for their aesthetic values. The commercial cultivars of gerberas are propagated through vegetative means by divisions of

clumps, but the multiplication by this method is too slow to be commercially viable (Kanwar and Kumar, 2008). Propagation through seed is not preferred as the plant exhibit heterozygosity and lack uniformity. Also, the improved semidouble and double cultivars do not set seed. Rapid multiplication could be accomplished through micropropagation technique (Van Son, 2007). Tissue culture procedure has been proven to be commercially practical in gerbera propagation. This method enables a million fold expansion per year of a desired plant (Murashige *et al.*, 1974).

Gerbera was micro propagated using various explants including shoot tips, floral buds, leaf, capitulum. Gerbera plantlets were produced from capitulum by various workers (Pierik *et al*.,1982; Modh *et al*., 2002; Tyagi and Kothari, 2004; Ray *et al.,* 2005; Mohammed and Ozzambak, 2007). The advantages of the capitulum method over shoot tip are the easier sterile isolation *in vitro* and it is also non-destructive, only inflorescences are used and no shoots are lost from the plant (Kanwar and Kumar, 2008). Pierik *et al*. (1975) obtained shoots from fully developed (mature) gerbera capitulum explants using a medium with 10 mg/l BAP. They rooted the resultant shoots *in vitro* in a medium containing 10 mg/l of either IBA or IAA and they obtained nearly 90 % rooting. Laliberte *et al*. (1985) reported that immature capitula 0.5 – 0.7 cm in diameter were up to 10 times as productive as fully developed ones. Radice and Marconi (1998) obtained shoots from fragments of young gerbera capitulum (diameter =1cm) explants using a medium with 2 mg/l BAP. They rooted the resultant shoots in MS medium containing 0.5 mg/l IBA and they obtained 70 – 100 % rooting of shoots. The use of liquid medium in tissue culture is often described as a means of reducing the cost of micro propagation (Alvard *et al*., 1993). The advantages include increased availability of water and dissolved substances to the explants and lower labour and production costs. Shoot production of *Rhododendron* was ten-fold higher in liquid medium than on agar-solidified medium (Douglas, 1984). Puchooa *et al*. (1999) compared the performance of *Nicotiana tabacum* leaf explants in MS medium either in liquid form (static, static with filter paper+glass beads as support, and agitated liquid medium) or solidified with Difco Bacto- agar and gelrite. They found significant differences between the supports used in terms of fresh weight, dry weight and number of shoots produced. Best response was obtained with liquid agitated medium. Macleod and Nowak (1990) found no differences in the regeneration capability of white clover using either agar solidified medium or liquid medium supported with small solid glass beads as matrix. According to the same authors, a 60% saving on media components can thus be made by substituting agar with beads. While some plants do not grow well in liquid medium others grow well in it (Pierik, 1987).

The objectives of this study was to examine the effects of BAP concentration, medium status (solid with agar versus liquid with cotton wool support), number of capitulum sections on shoot regeneration on capitulum explant and IBA concentration on *in vitro* rooting of shoots of the gerbera cultivar "Evergreen" in order to establish a protocol for micropropagation of this cultivar.

Materials and methods

This study was carried out at the tissue culture laboratory of the Date Palm Technology Company at Shambat, Khartoum North, Sudan.

Explant: For experiments one and two, young capitula (small flower buds) 0.5 – 1 cm in diameter were collected from greenhouse plants of the gerbera cultivar "Evergreen ”growing at a greenhouse belonging to the Central Trade Company (CTC), Khartoum North, Sudan. For sterilization, explants were first washed with running tap water for 15 minutes, then washed with detergent solution and rinsed with tap water. The explants were then taken to the laminar air flow cabinet where they were dipped in 70% ethanol for 10 seconds, followed by immersion in 15% commercial bleach (Clorox) to which was added 150 mgl^{-1} citric acid and 100 mgl^{-1} ascorbic acid as antioxidant solution with 2 drops /100 ml of tween 20 for 30 minutes with continuous shaking. They were then rinsed 3 times with autoclaved distilled water. After disinfestation each capitulum was divided and placed onto the medium.

Culture Media: For experiments one and two, the nutrient medium was composed of half MS (Murashige and skoog, 1962) inorganic salts and in mg/l: 10000 sucrose; 8000 agar; 80 adenine sulphate; 0.1 indole acetic acid (IAA). The pH of the medium was adjusted to 5.7 prior to agar addition using 0.1N HCl or NaOH. The medium was dispensed at 12.5 ml in 25×150 mm test tubes, plugged with aluminum foil and autoclaved at temperature of 121 ^oC and a pressure of 1.05 kg cm^{-2} for 15 minutes and left to cool in the culture room at temperature of 25±2^o C.

Culture conditions: The cultures were first placed in darkness for 2 weeks and subsequently placed under continuous florescent light at an intensity of 40.5 µmol m^{-2} s^{-1} and photoperiodic cycle of 16/8 light/dark hours and temperature of 25±2°C for another 6 weeks.

Experiment one: Effect of BAP concentration and medium status on shoot regeneration:

Five concentrations of BAP (0, 2, 4, 6, 10 mg l^{-1}) and two forms of medium (semi-solid form solidified with agar and liquid form supported with cotton wool) were tested as a two factor experiment. Each capitulum was divided into 4 segments and placed horizontally onto the medium that composed of half MS inorganic salts and in mg l^{-1}: 10.000 sucrose; 8000 agar; 80 adenine sulphate; 0.1 indole acetic acid (IAA).

Experiment two: Effect of number of capitulum sections on shoot regeneration: The capitulum was divided into 2,4,8,16 sections as treatments and cultured onto a nutrient medium composed of half MS inorganic salts and in mgl^{-1}: 10.000 sucrose; 8000 agar; 80 adenine sulphate; 0.1 indole acetic acid (IAA); 5 mgl^{-1} BAP.

Experiment three: Effect of IBA concentration on *in vitro* rooting of shoots: *In vitro* shoots resulting from experiments one and two were cultured in Magenta GA7 plastic culture vessels containing nutrient medium composed of half MS inorganic salts and in mg l^{-1}: 10.000 sucrose; 8000 agar; 80 adenine sulphate. IBA concentrations tested were 0, 0.5, 1, 2 mgl^{-1}.

Experimental design and statistical analysis

In experiment one, the five concentrations of BAP and the two forms of medium were combined as a two factor experiment in a completely randomized design with three replications. In experiments two and three treatments were arranged in a completely randomized design and replicated thrice as single factor experiments. Three explants represented an experimental unit. Statistical analysis was performed using SAS statistical software (SAS Inst. USA, V. 11, 2002). Mean separation was performed using Duncan's Multiple Range Test at 5% level of significance.

Parameters measured: Data were collected on percentage of responding explants (explants that form shoots), number of shoots/explant, rooting percentage, number of roots per shoot and root length.

Results and discussion

Experiment one: Effect of BAP concentration and medium status on shoot regeneration on capitulum explants

Percentage of responding explants

As shown in Table 1, the interaction between BAP concentration and medium status had a significant effect ($P \leq 0.05$) on percentage of responding explants. The highest percentage of responding explants (86.6 %) was recorded by solid medium supplemented with 4 mg l^{-1} BAP. BAP concentration had a significant effect ($P \leq 0.05$) on explant response. The highest percentage of responding explants (71.1 %) was shown at 4 mg l^{-1}. Medium status had no significant effect on explant response. However, the solid medium gave higher percentage of responding explants (45.9%) than the liquid one (33.3%). There was no explant response to the BAP- free medium.

Number of shoots/explant

Data presented in Table 2, showed that the interaction between BAP concentration and medium status had a significant effect ($P \leq 0.05$) on number of shoots/explant. The highest number of shoots/explant (4.77) was recorded by solid medium supplemented with 4 mg l^{-1} BAP. The concentration of BAP had a significant effect ($P \leq 0.05$) on number of shoots/explant. The highest number of shoots (3.72) was shown at 4 mg l^{-1}. The solid medium gave significantly higher number of shoots (2.37) than the liquid one (1.53). There was no shoot formation in BAP- free medium (Table 2). Using gerbera capitulum as explants, Van Son (2007) found that addition of 3 mgl^{-1} of BAP to MS medium resulted in maximum number of responding explants in "Arianna" variety, while addition of 5 mgl^{-1} BAP gave highest response in "Bonnie" variety, whereas, variety "Tobia" exhibited highest response on 10 mgl^{-1} BAP. Mohammed and Ozzambak (2007) obtained higher number of responding capitulum explants in the gerbera cultivar "Ameretto" at 7 and 10 mgl^{-1} BAP than at lower concentrations of 2 and 5 mgl^{-1} BAP. Pierik *et al.* (1975) found no response of gerbera capitulum explants to BAP- free medium. Laliberte *et al*. (1985) found maximum number of shoots on MS medium supplemented with 2 mgl^{-1} BAP from "Pastourelle" gerbera variety capitulum explant. Radice and Marconi (1998) also obtained axillary shoots from young capitulum of different gerbera cultivars on a medium that contained BAP at 2.0 mgl^{-1}. Van

Son (2007) obtained 7.40 shoots per explants on 3 mgl^{-1}BAP from "Ariaana" variety, 6.20 shoots on 5 mgl^{-1} BAP from "Bonnie" variety, whereas variety "Tobia" produced 5.40 shoots on 10 mgl^{-1} BAP. Pierik *et al*. (1975) used fully developed capitulum of gerbera as explants and reported that there was no shoot developed on cytokinin-free media and the optimum concentration of cytokinin was 10.0 mgl^{-1} BAP. These differences in capitulum explant response to shoot formation indicate that shoot formation on Gerbera capitulum explants depends on both cultivar and cytokinin level in the medium (Pierik *et al.*, 1982). Growth response in gerbera capitulum explant is said to be cultivar specific (Schiva *et al*., 1982; Pierik *et al*., 1982 and Harel *et al*., 1993) and every genotype has a specific range of optimum growth regulator concentration (Deepaja,1999). The differences noticed among different research workers could be attributed to genotypic differences and to the interaction effect of endogenous and exogenous growth regulators.

Plants differ in their response towards medium status either being solid or liquid. Pierik (1987) stated that some plants do not grow well in liquid medium others grow well in it. Working with several gerbera cultivars, Mohammed and Ozzambak (2007) showed that response towards medium status depends on the gerbera cultivar. Macleod and Nowak (1990) found no differences in the regeneration capability of white clover using either agar solidified medium or liquid medium supported with small solid glass beads as matrix. Shoot production of *Rhododendron* was found to be ten-fold higher in liquid medium than on agar-solidified medium (Douglas, 1984).

Table (1): Percentage of responding explants of the gerbera cultivar "Evergreen" as affected by BAP concentration and medium status two months after culture.

BAP concentrations (mgl^{-1})	Liquid medium (%)	Solid medium (%)	Mean
0	0.0 b	0.0 b	0.0 A
2	66.6 a	44.4 ab	55.5 AB
4	55.5 a	86.6 a	71.1 B
6	44.4 ab	66.6 ab	55.5 AB
10	0.0 b	44.4 ab	22.2 AB
Mean	**33.3 A**	**45.9 A**	

Means followed by the same letter "s" are not significantly different (P = 0.05) according to Duncan's Multiple Range Test.

Experiment two: Effect of number of capitulum sections on shoot regeneration on capitulum explants

Percentage of responding explants

Significantly (P≤ 0.05) highest response (76.6%) was obtained by cutting the capitulum into 8 sections followed by 4 sections and 16 sections. The lowest response (33.3%) was given by 2 sections.

Table (2): Number of shoots/explant of the gerbera cultivar "Evergreen" as affected by BAP concentration and medium status two months after culture.

BAP concentrations (mgl^{-1})	Liquid media (%)	Solid media (%)	Mean
0.0	0.0 a	0.0 a	0.0 A
2	1.91 ab	2.11 ab	2.05 ABC
4	2.66 ab	4.77 b	3.72 C
6	3.47 b	3.55ab	3.51 C
10	0.18 ab	2.48 ab	1.33 AB
Mean	1.53 A	2.37 B	

Means followed by the same letter "s" are not significantly different (P = 0.05) according to Duncan's Multiple Range Test.

Number of shoots/explant: As shown in Table 3, cutting the capitulum into 8 sections resulted in Significantly (P≤ 0.05) highest number of shoots/explant (6.55). Several workers used capitulum as explant in gerbera as it has remarkable advantage over shoot tip explant which costs the life of the plant from which it is taken (Tyagi and Kothari, 2004). Shoot development in capitulum explant might be due to the formation of meristematic tissues in segment of the immature flower heads (Mandal *et al.*, 2002). Shoot development from dormant buds situated in the axils of the bracts surrounding the receptacles of capitulum has also been reported by Pierik *et al.* (1975). Bhatia *et al.* (2012) divided immature gerbera capitulum into 4-8 sections and obtained 10 shoots/section in 11 weeks. Laliberte *et al*. (1985) divided immature gerbera capitulum (0.5- 0.7 cm in diameter) into 20 sections and obtained 12 shoots/section in 12 weeks. Mandal *et al.* (2002) divided immature gerbera capitulum into 12 pieces and obtained 5 shoots/piece. Genotypic differences might be responsible for such variation in results.

Table (3): Effect of number of capitulum sections on shoot formation in the gerbera cultivar "Evergreen "eight weeks after culture.

Number of capitulum sections	Percentage of responding explants (%)	Number of shoots/explant
2	33.3 a	2.25 a
4	66.6 ab	4.55 ab
8	76.6 b	6.55 b
16	66.6 ab	2.66 ab

Means followed by the same letter "s" in the same column are not significantly different (P = 0.05) according to Duncan's Multiple Range Test.

Experiment three: Effect of IBA concentration on *in vitro* rooting of shoots

Rooting percentage: As shown in Table 4, there was no significant difference between treatments in percentage of rooted shoots. However, the treatment 2 mg l^{-1} IBA gave the highest rooting percentage (86.6%) followed by the treatments 0.5 and 1 mg l^{-1} IBA (76.6%). The lowest percentage was given by the control (66.6%).

Number of roots per shoot: The highest value was significantly ($P \leq 0.05$) recorded by the treatment 2 mgl^{-1} (8.8 roots) and the lowest value (2.1 roots) was given by the control (Table 4).

Root length: There was no significant difference between treatments in root length. The treatment 0.5 mgl^{-1} IBA gave the highest root length (20.7 mm). The lowest root length (12.2 mm) was given by the control (Table 4). Different plant species and cultivars show different responses to IBA concentration in *in vitro* rooting. In sugarcane (*Saccharum officinarum*) the best *in vitro* rooting of microshoots was at 5.0 mg/l (Baksha *et al*., 2003). Cos *et al.* (2004) studied the optimal *in vitro* conditions to induce explant rooting of the 'Mayor'® peach-almond hybrid. They compared different IBA concentrations (1, 1.5, 2, 2.5 and 3 mg/l). The best inclusion in the culture media was 2 mg/l with a 73,6% success rate. In many previous studies gerbera shoots were rooted *in vitro* using different concentrations of different auxins with high success. Radice and Marconi (1998) obtained 70-100% rooting of gerbera shoots on MS medium supplemented with 0.5 mgl^{-1} IBA. Working with the gerbera cultivar Ameretto, Mohammed and Ozzambak (2007) obtained 100% rooting of shoots on MS medium supplemented with IBA at 0.5, 1, 2 mg/l and the highest number of roots per shoot was obtained at 1 mg/l. Pierik *et al*. (1975) obtained nearly 90% rooted gerbera shoots using IAA or IBA at a concentration of 10 mgl^{-1}. Such variation in results might be attributed to genotypic differences. As a conclusion, culturing young capitula (0.5 – 1 cm in diameter), cut into 8 sections onto half MS medium solidified with agar and supplemented with 4 mg l^{-1} BAP and *in vitro* rooting of the resultant shoots onto half MS medium fortified with 2 mg l^{-1} IBA can be suggested as a protocol for micropropagation of the gerbera cultivar "Evergreen".

Table (4): Effect of IBA concentration on root formation on shoots of the gerbera cultivar "Evergreen" two months after culture.

IBA concentration (mg l^{-1})	Percentage of rooted shoots (%)	No of roots per shoot	Root length (mm)
0	66.6 a	2.1 a	12.2 a
0.5	76.6 a	7.1ab	20.7 a
1	76.6 a	5.7 ab	19.1 a
2	86.6 a	8.8 b	17.2 a

Means followed by the same letter "s" in the same column are not significantly different (P = 0.05) according to Duncan's Multiple Range Test.

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Research paper

Enhancing Faba bean (*Vicia faba* L.) Productivity and Seed Quality Using Chemical Fertilizers in High Terrace Soil in the River Nile State, Sudan

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Abstract

Experiments were conducted at the Hudeiba Research Station Farm in the winter seasons of 2017/ 18 and 2018/ 19. The objectives were trying to improve faba bean production and seed quality using chemical fertilizers (nitrogen, phosphorus and potassium). The treatments consisted of eight fertilizers (nitrogen phosphorus, potassium, nitrogen + phosphorus, nitrogen+ potassium, potassium+ phosphorus and nitrogen+ phosphorus +potassium and control, 21kg N/ha,43kg P_2O_5/ha and 45.22kg K_2O/ha). The treatments were arranged in randomized complete block design (RCBD) with four replicates. Significant differences were found between the fertilizers as reflected on the number of pods per plant and total seed yield. Also, significant differences were observed in all other measured characters due to application of the nitrogen+ phosphorus +potassium fertilizers treatment in the two successive seasons. The nitrogen+ phosphorus potassium gave the best grain yield compared to all other fertilizer treatments. Nonetheless, carbohydrates%, starch%, protein% were increased when 21kg N/ha,43kg P_2O_5/ha and 45.22kg K_2O/ha dose, was applied. As well as the total flavonoids contents in faba bean (*Vicia faba* l.) was improved when 21kg N/ha ,43kg P_2O_5/ha and45.22kg K_2O dose was applied. Economic feasibility was tested using gross-rate (GR) analysis. The GR can be calculated by dividing gross profit by net sales. Economically, the results showed that the nitrogen+ phosphorus+ potassium dose gave the highest GR ratios (146%) compared to the other fertilizers, in the two successive seasons. Nitrogen+ phosphorus+ potassium is the best option for faba bean farmer in the River Nile State to be adopted for profitable yield.

Keywords: Chemical fertilizers, faba bean, gross rate of return, high Terrace

تحسين إنتاجية الفول المصري (*Vicia faba* L.) وجودة البذور باستخدام الأسمدة الكيماوية في تربة التروس العليا بولاية نهر النيل، السودان

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المستخلص

أجريت التجارب في مزرعة محطة أبحاث الحديبة في فصل الشتاء 18/2017 و19/2018. بغرض محاولة تحسين إنتاج الفول وجودة البذور باستخدام الأسمدة الكيماوية (النيتروجين والفوسفور والبوتاسيوم). حوت المعاملات ثمانية من تكوينات الأسمدة (نيتروجين، فسفور، بوتاسيوم، نيتروجين + فوسفور، نيتروجين + بوتاسيوم، بوتاسيوم + فوسفور ونيتروجين + فوسفور + بوتاسيوم وضبط، 21 كجم / N هكتار، 43 كجم / P_2O_5 هكتار و45.22 كجم / K_2O هكتار.). تم ترتيب المعاملات في تصميم القطاعات كاملة العشوائية (RCBD) بأربعة مكررات. وجدت فروق معنوية بين الأسمدة حيث انعكست على عدد القرون لكل نبات وإجمالي إنتاج البذور. كما لوحظت فروق معنوية في جميع الصفات المقاسة الأخرى تعزى إلى استخدام معاملة النيتروجين + الفوسفور + الأسمدة البوتاسية في الموسمين المتتاليين. كانت الفروق بين الأسمدة ذات دلالة إحصائية عالية في كل من حاصل البذور وعدد القرون للنبات. أعطى النيتروجين + الفوسفور + البوتاسيوم أفضل محصول حبوب مقارنة بجميع معاملات السماد الأخرى. ومع ذلك تمت زيادة النسبة المئوية للكربوهيدرات، النشا، البروتين عند تطبيق تلك الجرعة وكذلك تم تحسين محتوى الفلافونويد الكلي في الفول (Vicia faba L.) عند تطبيق جرعة 21 كجم نتروجين/هكتار، و43 كجم / P_2O_5 هكتار و45.22 كجم /K_2O هكتار. تم اختبار الجدوى الاقتصادية باستخدام تحليل العائد الإجمالي (GR) يمكن حساب GR بقسمة إجمالي الربح على صافي المبيعات. من الناحية الاقتصادية أظهرت النتائج أن جرعة النيتروجين + الفوسفور + البوتاسيوم أعطت أعلى نسب GR (146) ٪مقارنة بالأسمدة الأخرى في الموسمين المتتاليين. أثبتت النتائج ان النيتروجين + الفسفور + البوتاسيوم هو الخيار الأفضل لمزارع الفول المصرى في ولاية نهر النيل لاعتماده لتحقيق عائد مربح.

كلمات مفتاحية: الاسمدة الكيمائية، الفول المصري، معدل العائد الإجمالي، التروس العليا

Introduction

Faba bean (*Vicia faba* L.) is considered as one of the most favored winter-sown legume crop worldwide. It is an important crop with high protein and carbohydrates (Sepetoglu, 2002). Four main functions in the agro-ecosystems are provided by the crop: first giving food and feed rich in protein; second it increases soil fertility by symbiotic N_2 fixation; third if preceded, faba bean reduces constraints on growth and yield by the other crops in the rotation. In general, legumes are rich in nutritive value as animals feed as well as maintaining soil fertility and productivity (Mohammed and Elsheikh, 2014). Faba bean is considered as one of the most important cool-season food legumes produced in the River Nile State (RNS). The production is consumed

domestically. However, the often low production of the crop achieved by growers enforces researchers at Agricultural Research Corporation (ARC) to conduct more experiments to enhance both yield and quality. Considerable efforts were directed towards improving yield and protein content of faba bean through breeding, fertilization and improving cultural practices in Sudan. In improving agriculture production, low soil fertilizer is considered one of the major critical constraints (Ayoub, 1999). The regularly mono-cropping practices and crop intensification resulted in poor soil fertility that make application of fertilizers of must to enhance both faba bean production and quality in River Nile state.

The objectives of this research are to increase faba bean production using NPK fertilizers and the effect of them on carbohydrates, starch, protein, and flavonoids accumulation during faba bean seed development and maturation in RNS.

Materials and methods

This trial was conducted at Hudeiba Research Station Farm (17^0 34' N, 33^0 56' E 350 meters above sea level) located in the River Nile State. The local climate is semi-desert with an average annual rainfall of about 200 mm (Adam, 2005). The experimental site falls in high terrace series which is classified as Chromic Haplostorrts, Aridsol. Soil samples were taken from two depths (0-30 and 30-60 cm) from the site and analyzed for chemical and physical properties. Table (1) shows some physical and chemical properties of these High terrace soils. The soil is characterized by being low in Nitrogen, Phosphorous and organic Carbon, with calcareous, slightly sodic and clay matrix. The treatments consisted of eight fertilizers combinations (nitrogen, phosphorus, potassium, nitrogen+ phosphorus, nitrogen+ potassium, potassium+ phosphorus and nitrogen+ phosphorus potassium and control, 21kg N/ha, 43kg/P_2O_5/ha and 45.22kg K_2O/ha. Fertilizers form used were urea, triple super phosphate and potassium sulphate as sources of nitrogen, phosphorus and potassium. Two faba bean varieties were tested (Basabeer and Hudieba 93). The treatments were arranged in randomized complete block design (RCBD) with four replicates. As application and timing, the fertilizers phosphorus was added at sowing in furrow of the ridges. Nitrogen fertilizer was applied at sowing. While potassium fertilizer has been added in two phases of growing stages; first at sowing and second after one month from crop establishment. Faba bean varieties were directly planted on ridges 60 cm apart with intra-row spacing of 20 cm, and 2 seeds per hole. Plot size was (6×6m). In both seasons sowing was on 26th October and the irrigation was carried out every 7 days regularly. All other cultural practices were applied as recommended by (ARC), Sudan.

Crude protein (CP) content was determined by the Kjeldahl method (N ×factor of 6.25) using a Kjeltec Auto 1031 Analyzer (Foss Tecator, Sweden). For the determination of crude protein yield (CPY) the following expression was used:

$$CPY = CP \times SY/100 \ldots$$ (Barłóg *et al*., 2019).

The collected data included: plant height (cm), number of branches per plant, number of pods per plant, pods weight (g), 100 Seeds weight (g) and seed yield (ton/ha).

The gross rate of return on an investment is one measure of a project or investment's gross profit. It typically includes capital gains and any income received from the investment. Also gross rate is the rate of interest that you would earn at the beginning of taking out a savings account. It's useful as a rough guide. By comparison, the net rate of return deducts fees and expenses from the investment's final value. Once you determine gross profit, you can calculate the gross profit rate by dividing gross profit by net sales. The formula for gross rate of return is:

GR= (Final value – initial value)/ initial value

Results

Agronomic performance of faba bean (*Vicia faba* L.) was significantly affected by the treatments of chemical fertilizers over control. Tables (2 and 3) showed the effect of nitrogen+ phosphorus+ potassium on the grain yield and some other growth and yield components of two faba bean varieties (Basabeer and Hudeiba 93) in seasons 2017/18 and 2018/19. Results indicated significant effect of fertilization on all studied parameters. Fertilizer treatments, compared to control, increased plant height, number of branches per plant, number of pods per plant, pods weight, 100 Seeds weight and seed yield with the two varieties in both seasons. The highest seed yield was obtained by NPK (nitrogen+ phosphorus+ potassium) treatment with the two varieties in both seasons (3.9 for Basabeer and Hudeiba 93 in the first season and 4.2 and 3.6 ton/ha for Basabeer and Hudeiba 93 in the second season, respectively).

Results showed that the maximum plant height (cm), number of branches per plant, pods weight(g), 100 seeds weight(g) were also achieved when 21kg N/ha, 43kg P_2O5/ha and 45.22kg K_2O were applied in both seasons for the two faba bean varieties. Differences in results between seasons were attributed to that temperature in first season was lower than the second one.

Table 4 showed that the carbohydrates%, starch%, protein%, and total flavonoids were significantly increased by fertilizer treatment compared to the control ($p \leq 0.05$). The highest values were obtained by NPK treatment (55.11, 43.13, 28.04 and 6.01for carbohydrates%, starch%, protein%, and total flavonoids respectively).

Table (5) showed the gross profit rate for the different treatments applied. Fertilizer treatment 21kg N/ha ,43kg P_2O_5/ha and 45.22kgK_2O achieved gross rate of about146%.

Discussion

In All parameter fertilizer treatments over yield the control. Results also indicated best performance of the fertilizers treatment (nitrogen + phosphorus + potassium) over the other fertilizers treatments. Similar results were obtained by Mohammed and Elsheikh (2014) when they used chemical fertilizer in crop plant like carrot. Among nitrogen, phosphorus and potassium, the essential nutrients required by crop plants, nitrogen is the most commonly deficient in tropical soils. However symbiotic fixation is expected to compensate this deficiency in faba bean. High Terrace soils in Northern Sudan is mostly deficient in phosphorus so any addition of it is expected to increase yield. In an experiment on *Zea Mays* conducted by Al-Farhan and Al-Rawi (2002), they found that increasing phosphorus up to 80 kg/ ha increased

yield. Mona *et al*. (2011) also confirmed that among 0, 40 and 80kg/ ha phosphorus, 80kg/ ha produced the highest yield. Unlike others, Taha *et al.* (2016) found that the increase of plant available K in soil resulted in a lower tannin content, especially in mature seeds. To ensure a high yield of protein, the soil should be also characterized by a high content of available K. In soil with low or medium K content, Abou-Salama and Dawood (1994) found that increasing phosphorus up to 90 kg/ha could increase yield production. One of the most important reasons for non-significant effect of phosphorus on the yield of faba bean is its low efficiency in soil due to low solubility and sorption by calcareous and alkaline soils which is the typical case in the high terrace. In this study, faba bean crop gave high increase in seed yield and all yield components when the crop is fertilized with nitrogen + phosphorus + potassium fertilizers. Nonetheless, nitrogen+ phosphorus+ potassium gave the highest significant influences compared with other treatments. These differences appeared on the number of pods per plant, 100 seed weight ($P \leq 0.05$) and the total grain yield ($P \leq 0.05$). Likewise, Mani (2002) cited that increase in NPK led to a significant increase in plant height and grain yield. Barłóg *et al*. (2014) and Barłóg *et al.* (2019) stated that K fertilization causes slim increase in Lys and Cys amino acids in faba bean seeds. Results of carbohydrates%, starch%, protein%, and total flavonoids were influenced by fertilizer sources ($p \leq 0.05$). Crude protein (CP) as a nitrogen molecule is expected to increase with increasing nitrogen fertilizer treatments. Also, crude protein increased on applying P and K treatments, and interaction between these fertilizers. It is obviously observed that the rates of carbohydrates, starch, protein were increased when NPK dose was applied. Further, the total flavonoids contents in faba bean (*Vicia faba* l.) were increased when 21kg N/ha ,43kg P_2O_5/ha and 45.22kg K2O dose was applied.

Conclusion

Based on the results of this study the followings can be concluded; the addition of 1N (21Nkg/ha) + 1P (43 P_2O_5kg/ha) + K_2O (45.22 K_2Okg/ha) showed significant effects on faba bean yield in high terrace soils. The potassium sulphate, nitrogen and phosphorus gave the best seed yield, and seeds quality. The nitrogen phosphorus potassium realized the best economic feasibility (GR%= 146%) for growing faba bean in the River Nile State, Sudan.

Table (1): Soil properties of four analyzed auger samples of the experimental site (High terrace).

EC_e	SAR	ESP	O.C%	$CaCO_3$%	K Meg/l	P PPm	N PPm	Sand%	Clay%	Silt%
2.5	10.0	11.0	0.106	9.0	2.210	1.9	140	61	36	3
1.7	9.0	9.6	0.102	8.0	1.316	2.0	220	58	40	2
2.5	11.0	12.1	0.123	8.0	2.014	2.0	231	62	35	3
2.3	9.0	11.2	0.305	7.0	2.O26	2.1	224	56	40	4

Source Hudeiba soil lab Station, EC_e= Electrical Conductivity of Saturation Extract.
O.C = Organic Carbon, SAR=Sodium Adsorption Ratio, ESP=Exchange Sodium percentage.

Table (2): Effect of chemical fertilizers on plant height, number of branches per plant, pod weight, 100 seeds weight and yield (ton/ha) of faba bean during seasons 2017/18 at Hudeiba Research Station Farm.

Treat meant	Plant height (cm)	No. of branches/plant	Pod weight (g)	100Seeds weight (g)	Yield (ton/ha)
Basabeer					
21kghaN	100	5	8.12	59	2.6
K_2O	100	5	7.54	61	2.6
P_2O_5	103	6	7.91	60	2.7
$N+K_2O_5$	111.60	7	9.14	64	3.0
$N+P2O_5$	114	8	11.52	69	3.1
$P_2O_5+ K_2O$	126.8	7	12.1	63	3.0
$N+P_2O_{5+}K_{2O5}$	126.8	9	13.91	74	3.9
Control	85.6	4	7.00	56	0.7
Mean	106.1	6.4	9.4	55.2	2.8
L.S.D	3.65	1.0	1.87	4.9	.21
C.V %	10.8	3.00	5.4	15.5	.63
Hudieba 93					
N	109	5	7	61	2.7
K_2O	108	6	7	64	2.8
P_2O_5	100	6	8	64	2.8
$N+K_2O$	115	7	8	65	3.0
$N+P_2O_5$	120	7	9	67	3.1
$K_2O+ P_2O_5$	123	8	12	60	3.0
$N+ P_2O_5 +k_2O$	130	9	14	71	3.9
Control	100	4	6	52	0.6
Mean	115	6.7	8	63.1	3.2
L.S.D	1.54	1.9	1.0	2.1	0.83
C.V %	5.51	5.76	3.0	6.3	2.6

Significantly differences at $P \leq 0.05$ level.

Table (3): Effect of chemical fertilizers on plant height, number of branches per plant, pod weight, 100 seeds weight and yield (ton/ha) of faba bean during seasons 2018/19 at Hudeiba Research Station Farm

Treat meant	Plant height(cm)	No. of branches/plant	Pod weight (g)	100 Seeds weight (g)	Yield (ton/ha)
Basabeer					
21kg/haN	99.12	4.97	7.10	56	2.1
K_2O	100	4.80	8	64	2.2
P_2O_5	101	5.90	8.10	62	2.8
$N+K_2O_5$	109	6.99	9.21	63	3.3
$N+P2O_5$	114	8.40	12	71	3.1
$P_2O_5+ K_2O$	124	7.54	13	65	3.1
$N+P_2O_5+K_{2O}$	123	9.45	12.90	77	4.2
Control	86.10	4.21	6.99	54	.83
Men	107	6.4	9.7	64	2.7
L.S.D	2.8	.67	1.34	3.1	.25
C.V	11	3.9	6.1	11	.73
Hudieba93					
N	111	5	6.6	67	2.9
K_2O	112	6	6.8	69	2.6
P_2O_5	102	6	8.3	68	2.5
$N+K_2O$	113	7	8.4	68	3.4
$N+P_2O_5$	118	7	9.4	69	3.2
$K_2O+ P_2O_5$	1120	8	12.40	64	3.3
$N+ P_2O_5 +k_2O$	127	9	14.50	75	3.6
Control	101	4	6.45	49	.71
Mean	112	6.6	6.5	65	2.8
L.S.D	.33	1.9	.90	2.2	0.89
C.V %	6.4	5.76	6.7	4.2	2.8

Significantly differences at $P < 0.05$ level.

Table (4): Effect of chemical fertilizers treatments and varieties of faba bean seeds season 2017/18 and 2018/19

Treatment	Carbohydrates %	Starch%	Protein %	Total flavonoids (mg/g)
Basabeer				
21kgN/ha	45.53	34.21	21.10	2.88
45.22kgK_2O/ha	49.14	34.44	22.76	3.0
43kgP_2O_5/ha	50.12	35.11	23.12	4.19
21kgN/ha+ 45.22kgK_2O/ha	51.17	35.32	24.41	4.99
21kgN/ha+ 43kgP_2O_5/ha	52.10	38.15	24.78	5.06
43kgP_2O_5/ha+ 45.22kgK_2O/ha	51.11	35	24	5.93
21kgN/ha+ 43kgP_2O_5/ha + 45.22kgK_2O/ha	55.11	43.13	28.04	6.01
Control	42.17	30.19	19.19	1.53
LSD	0.07	0.15	0.05	0.06
Hudieba 93				
21kgN/ha	48.17	31.	21.10	2.85
45.22kgK_2O/ha	50.23	32.13	22.76	2.97
43kgP_2O_5/ha	51.12	33.77	23.12	4.15
21kgN/ha+ 45.22kgK_2O/ha	51.51	33.97	24.41	4.65
21kgN/ha+ 43kgP_2O_5/ha	52.65	35.76	24.78	4.78
43kgP_2O_5/ha+ 45.22kgK_2O/ha	52	34	24.1	4.1
21kgN/ha+ 43kgP_2O_5/ha + 45.22kgK_2O/ha	57.13	39.89	28.04	5.55
Control	44.1	28.90	19.19	1.34
LSD	0.05	0..18	0.05	0.06

Source: food research center

Table (5): Faba bean combined cost items and the gross rate for one hectare using different fertilizers in seasons 2018/19 and 2019/20

Fertilizers	Total produce MT/ ha.	Net sales SDG / ha.	Total cost SDG / ha.	Gross profit SDG / ha.	Gross profit rate	GR %
21kgN/ha	2.6	312000	127330	184670	1.450326	145
45.22kgK_2O/ha	2.6	312000	138040	173960	1.260214	126
43kgP_2O_5/ha	2.7	324000	142800	181200	1.268908	127
21kgN/ha+ 45.22kgK_2O/ha	3.0	360000	146370	213630	1.45952	146
21kgN/ha+ 43kgP_2O_5/ha	3.1	372000	151130	220870	1.461457	146
43kgP_2O_5/ha+ 45.22kgK_2O/ha	3.0	360000	161840	198160	1.224419	122
21kgN/ha+ 43kgP_2O_5/ha+ 45.22kgK2O/ha	3.9	448000	170170	277830	1.632661	163
Control	0.7	84000	119000	-35000	-0.29412	-29.4

Source: Authors calculation

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Research paper

Palm Dates Marketing and Economics in River Nile State of North Sudan

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Abstract

This research looks to study the palm date products marketing, constraints faced and how the dates business could be promoted in River Nile State of Sudan, in particular, and in other producing countries in the region as general. The study depends mainly on primary data that collected by using structured questionnaires for 50 randomly selected palm dates growers from the State. Secondary data is also employed; they have been collected from various relevant sources. Descriptive statistical analysis has been applied to achieve the objectives of the research. The research unveiled that agricultural marketing system in the area of study suffered from numerous chronic obstacles such as products prices instability, inadequate marketing infrastructure and high cost of marketing. The study concluded that stability and improvement of dates marketing system contribute significantly to farm sustainability and combat malnutrition in the State. However, the poor marketing system in the State restrict dates production as well as the sustainability of this strategic crop. The study finds that the conventional farming system of dates will need to be addressed by gradually shifting to modern one and accordingly provide incentives to make dates more profitable. So, the cooperation between international organizations and governmental institutions should tackle the constraints of dates marketing system in the region.

Keywords: Palm date, development, marketing, north Sudan

تسويق واقتصاديات تمور النخيل في ولاية نهر النيل بشمال السودان

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المستخلص

يهدف هذا البحث إلى دراسة تسويق منتجات تمور النخيل والمعوقات التي تواجهها وكيفية الترويج لتجارة التمور في ولاية نهر النيل بالسودان على وجه الخصوص وفي الدول الأخرى المنتجة للتمور في المنطقة بشكل عام. اعتمدت الدراسة بشكل أساسي على البيانات الأولية التي تم جمعها باستخدام استبيانات منظمة لعدد 50 مزارع نخيل تم اختيارهم عشوائياً من الولاية. تم استخدام البيانات الثانوية أيضًا والتي تم جمعها من مصادرها المتعددة وذات الصلة. تم تطبيق التحليل الإحصائي الوصفي لتحقيق أهداف البحث، وقد كشف البحث عن أن نظام التسويق الزراعي في منطقة الدراسة يعاني من العديد من العقبات المزمنة مثل تقلب أسعار المنتجات وعدم كفاية البنية التحتية للتسويق وارتفاع تكلفة التسويق. وخلصت الدراسة إلى أن استقرار وتحسين نظام تسويق التمور يساهم بشكل كبير في استدامة مزارع التمور علاوة على مكافحة سوء التغذية بالولاية إلا أن ضعف نظام التسويق في الدولة يقيد إنتاج التمور واستدامة هذا المحصول الاستراتيجي. توصلت الدراسة إلى أن نظام الزراعة التقليدية للتمور يحتاج إلى المعالجة من خلال التحول التدريجي إلى النظام الحديث، الامر الذي يتطلب تقديم حوافز لجعل التمور أكثر ربحية. لذلك فإن التعاون بين المنظمات الدولية والمؤسسات الحكومية يمكن ان يساهم في معالجة معوقات نظام تسويق التمور في المنطقة .

كلمات مفتاحية: تمور النخيل، تنمية، تسويق، شمال السودان

Introduction

Market is considered as the embodiment of all services and goods activities of a producer to obtain a profit from production. Thus, marketing of products does not start from post-harvest, but from the cultivation time of the crop. Accordingly, the producers and traders should consider the specific characteristics of the marketable surplus of agricultural product, like perishables, the annual demand and supply and crop prices. At present (in 2016), the Arab Region is the world leader of date cultivation with almost 75% of global area under date palm, around 77% of world production and approximately 69% of world total export of dates (Dhehibi *et al.*, 2016). The main consumers of dates in Europe are found in the large and growing Muslim community that mainly consists of people who emigrated from North Africa, South Asia and the Middle East. Date palm market grows at 5.2% CAGR to reach 13,482.48 kilo tons by 2025. Export and product pricing statistics, and trends (Adroit Market Research, 2019). According to the United Nation's Food and Agriculture the Middle East date palm consumption accounted for over two-third of the global market in 2018. Over the past few years, European dates import is continuing. Traditionally, date fruits are consumed during Ramadan. The Muslim calendar is based on the moon cycle and therefore the dates of Ramadan vary from year to year. Some studies mentioned that marketing is recognizing consumer behavior, measuring it, converting this information to planning production to meet the needs. In other words, marketing is a conscious effort to create an efficient allocation of resources and creating a kind of expertise in the market. Organizations must find their target market to better identify their needs to develop and provide products and services tailored to them. The base of marketing effort is to avoid wasting resources and different

facilities. Marketing means segmenting or market regulation and determining products for the most appropriate markets. Also, Scheer and Zallinger (2007) reported that, today, in most countries of the world, small and medium enterprises play a key role in job creation and economic development of communities. Necessary studies on the potential of sustainable economic growth have not been fully articulated so far, often due to a specific set of problems and obstacles for small and medium enterprises (SMEs) related to their size and relations. These production units are not capable of receiving and capturing market opportunities that require large quantities, homogenous standards and regular supply individually. In this regard, their experience difficulties in achieving economies scale in the purchase and supply of inputs such as equipment, raw materials, financing, consulting services and so on acts as a deterrent.

The failure of agricultural marketing system in northern Sudan is considered as one of the most factors that contribute to constraints to attain the objectives of agricultural development and farm sustainability and income of farmers. In other words, failure of agricultural development has a direct effect on political, cultural, social and economic aspects. Elfeil (1993) stated that in the Northern State, the marketing is thought to be the most important factor constraining the agricultural production.

Thus, attention to the agricultural marketing and marketing policies could increase agricultural production and lead to sustainable farms in the region, decrease unemployment, raise exports, create access to other regional and overseas markets. The marketable surplus of crops in northern region could be described as free of State involvement. Food and cash crops such as legumes, cereal and fruits are often sold immediately post-harvest at very low farm gate prices. The farmers usually enforced to sell their crops immediately post-harvest due to the need for cash and the high cost of transportation to urban centers. The production and marketable surplus of palm dates in Sudan is faced by numerous constraints, namely, low yield and high cost of inputs coupled with conventional varieties, poor technology, lack of financial incentives, lack of awareness of farmers and difficulties to access the international markets, lack of public investment in infrastructure and marketing systems, lack of research and training and extension, knowledge and relationship with the academic institutions. Palm dates in Sudan are produced under a conventional farming system without paying attention to irrigation water requirements, fertilization or other agricultural practices.

This research was conducted in Northern region of Sudan. The available agricultural land of the region is located along the River Nile banks. These areas are characterized by a high population density with the majority work in agriculture (Ahmed, 2009). Generally, this study aims to suggest options to promote dates marketing by finding permanent and stable national and overseas markets. Sudan has the opportunity to promote its palm date production to be compatible with international standards in terms of packaging and quality to reach global markets.

Methodology

This research was carried in 2017 at El-Ketiab scheme of River Nile State (RNS) where perennials are commonly produced under surface irrigation system by using pumps at the River Nile and to some extent from underground water. Elketiab scheme was established in 1917. The study selected this scheme mainly due to the high portion of perennials (71%). The scheme is well organized, the total area of the scheme is 6200 feddans, of which 4690 feddans are owned by the government, while the remaining area of 1510 feddans are owned by farmers. The total area of the scheme is distributed among 389 farms (*hwasha*) along Elketiab villages. The total number of tenants in the scheme is about 1687 tenant. Delivery of irrigation water for the scheme also depends on pump irrigation from the River Nile (RN). The main crops are perennial crops such as date palms, citrus fruits, mangos, guava and alfalfa. Irrigation water is supplied all over the year to irrigate the perennial crops. The main pump stations for the scheme are located at Elketiab and Elmuslmab. Irrigation water is conveyed to the cultivated area of the scheme that covers about 5000 feddans for both perennial and seasonal crops when they exist simultaneously. The agricultural system of the RNS is characterized mainly as semi-mechanized system. The perennials are considered the main cash crops in the tenancies system beside some food crops namely cereal and legume crops. Recently, the animal production activities are enlarged as well as oil crops. This research is considered as quantitative. In this study, to determine the dates farming system, random sampling method was used and the number of samples were selected in probability proportional method to the scheme tenants.

Area of the study

The research was conducted on date palm production and marketing in El-Ketiab public irrigated scheme in the River Nile State. The scheme is considered as one of the main suppliers of fruit products in the district where dates and citruses are commonly produced under surface irrigation from pumps on the River Nile.

Sources of data

Both primary and secondary data were applied in the study. The primary data were collected through a field survey by using questionnaires to interview date-palms growers. Secondary data were collected from relevant sources such as records of the State Ministry of Agriculture, previous studies and the internet.

Sampling

Probability proportional method was used and 50 tenants, selected randomly, forming about 3% of the total tenants in the scheme. The dates producing zone in Sudan were stratified into the two geo-administrative zones of Northern Sudan comprising the Northern and River Nile States, and central Sudan represented by Khartoum State.

Data collection

Field questionnaires were administered for 50 date-palms growers in El-Ketiab public irrigated scheme. In addition to the use of questionnaires, field observations, farmer consultations and farm visits were also made. Data collected was mainly on production, production costs, product marketing and returns, as well as on constraints facing palm dates growers and traders.

Data analysis

A set of analytical techniques were employed including descriptive statistics and farm partial budget technique is used to derive gross margins for different crops of at El-Ketiab scheme. The definition of gross margin is the enterprises gross returns less the variable costs attributed to it. The gross returns are the value of production of the enterprise, whereas variable costs refer mainly to production inputs which differ according to the size of those enterprises. In this technique some of the basic data was used to calculate gross returns. Gross margins reveals how much a firm (farm, company etc.) earns taking into consideration the costs that it incurs for producing its products and/or services and it could be expressed as a percentage. Gross margin is a good indicator of how profitable a firm is at the most fundamental level. Farms with higher gross margins will have more money left over to spend on other activities such as investment, improvement of production and marketing.
Equation (1) is the general mathematical form for the gross margin calculation per crop:

$$GM = GR - TVC \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where:

GM = Crop gross margin per fed in Sudanese Pound SDG,

GR = Crop gross revenue per fed in SDG and

GM = TVC: Crop total variable costs per fed in SDG.

Results and discussions

The palm date sub-sector in Sudan is improving less than expected. It still characterized with unsatisfied prices and hence, low returns causing dates improvement negatively. As far as dates industries are concerned it is known that most cultivars are of the dry type; hardly suited for exportation and international competition. They are predominantly consumed as fresh or dry fruits in various parts of the country but some is used to make a native drink like alcoholic drink or vinegar.

Socioeconomic characteristics

The socioeconomic characteristics of the palm dates growers are expected to have a great effect on the production process in the study area, in addition to increasing palm dates yield and household incomes. The main collected socioeconomic information was on tenants' education level, marital status, age, family size, family contribution on field work, years of experience, occupations in and/or out farm, distance between the tenants' home and field, farm size of

tenants, and land tenure beside some data regarded their farm activities. Table 1 represents the major socioeconomic characteristics of El-Ketiab scheme tenants.

Table (1): Major socioeconomic characteristics of the surveyed tenants

No.	Indicator	Mean	STD
1	Age	50	12.5
2	Family size	9.5	5.4
3	Years of experience	31.5	14.9
4	Farm size	8.5	5.5
5	Distance from tenants' resident to the farm	1.7	4
6	Number of family labor	2	1.8

Source: field survey by authors

The analysis of the main economic and demographic data of the surveyed date palms growers unveiled that their average age was about 50 years, while the family size averaged 10. Those date growers reflected high cumulative date planting experience averaging 32 years. The farm size in area of the study is considered as small holding, it varied from 1 to 27 feddans per farm household, with the majority of tenancies (64%) being run on rent basis. In El-Ketiab scheme farming system date palms occupied for 13%, while citruses accounted 53% of the total farm land. The level of education of farmers, at a particular point, can affect the adoption of modern technologies and improvement of the date palms farm system. The research found that all the surveyed tenants were educated and all of them were males. As high as 76% of them were fully occupied with their farms and about 82% had the engagement of an average of two members of their families in farm production.

International marketing of palm dates

Date production is a world agricultural industry producing about 5.4 million metric tons of fruit. The date fruit, which is produced largely in the hot arid regions of South West Asia and North Africa, is marketed all over the world as a high-value confectionery and fruit crop and remains an extremely important subsistence crop in most of the desert regions. The world production of dates has increased from about 1.8 million tons in 1961 to 2.8 million in 1985 and 5.4 million in 2001. The increase of 2.6 million tons since 1985 represents an annual expansion of about 5% (FAO, 2017). The international markets of dates such as Europe, Asian and Africa markets are considered as important markets in terms of value, even though they import relatively varied quantities of dates. EU markets compared to Asian ones are still imports relatively small quantities of dates, it accounts for 10% of world imports in volume with some 50,000 tones, and they account for some 30% in value. This reflects the fact that EU import prices for dates are comparatively much higher than the world average. The main palm date producers and supplier in the world markets are situated in the North Africa and Middle East.

The palm dates are imported from numerous countries namely, Saudi Arabia, Iran, Tunisia, Palestine and South Africa. Saudi Arabia, Palestine and Tunisia are mainly composing the date palm markets of the products in respect of the quality standard. While the palm dates

from Iran is less quality when compared to the above mentioned countries that why it is characterizing with less prices in the international markets. Table 2 and Table 4 illustrate the distribution of date palms by country for the major date producing countries and till 2001, Iran, Saudi Arabia and Iraq had almost 50% of the harvested area of the world.

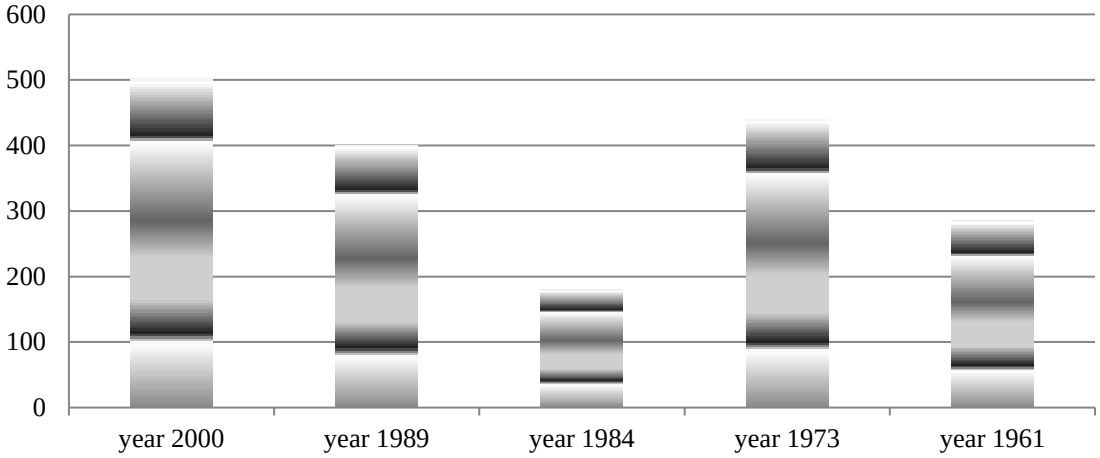
Table (2): Main date producing countries (000 tones)

Supplier	2001	% of world	% change 1991-2001
Egypt	1,102	20.6	67
Iran	900	16.8	42
Saudi Arabia	712	13.3	35
Pakistan	550	10.3	88
Iraq	400	7.5	-29
Algeria	370	6.9	75
UAE	318	5.9	84
Oman	260	4.9	93
Sudan	177	3.3	26
Morocco	32	0.6	-31
World	5 353	-	43

Source: Adapted from FAO (2001) data.

Table (2) shows that in 2001 the top five palm date producing countries were Egypt, Iran, Saudi Arabia Pakistan and Iraq, accounting for about 69% of total world production. If the next five most important countries are included, i.e. Algeria, United Arab Emirates, Sudan, Oman and Morocco, then this percentage rises to 90%. This clearly indicates that most of the world's date production is concentrated in a few countries in the same region. Table (2) also reflects illustrates the major date producing countries have steadily stretched production over the 1990th decade, representing a 43% increase over that decade. Over same period (1990th), date exports increased. Increase has been rapid in Oman, the United Arab Emirates, Egypt and Pakistan. Conversely, output decreased in Iraq (due to the trade embargo- from 248 tones in1989 to 20 tons in 2001) and Morocco (due to phytosanitary problems). The international production and trade in palm dates can be fluctuated; changes are often associated with many factors such as political and economic instability in the major producing countries. Unfavorable climatic factors can also affect production and storages. Asia dominates the export market by far in terms of volume (i.e. UAE and Iran), but further analyses show that North Africa has 26% of the market in terms of value (Tunisia and Algeria achieve high export prices), while it represents only 8% in terms of quantity. This is a clear reflection of North Africa's strategy to target the high value markets of Europe. Asia on the other hand is exporting lower quality dates at much lower prices, mainly to India. Europe, predominantly France - a non-producing region - has 5 percent of the market share through its re-exports of dates originating from North Africa. FAO (2017) reported that an average of almost 500,000 tons of dates was exported annually with a total value of about US$258 million. When this figure is compared with total production, it is clear that the bulk of the dates produced are consumed within the producing countries. Of the 500 000 tons exported, 225 000 tones were imported by India, 150 000 tones by the United Arab Emirates (UAE) and

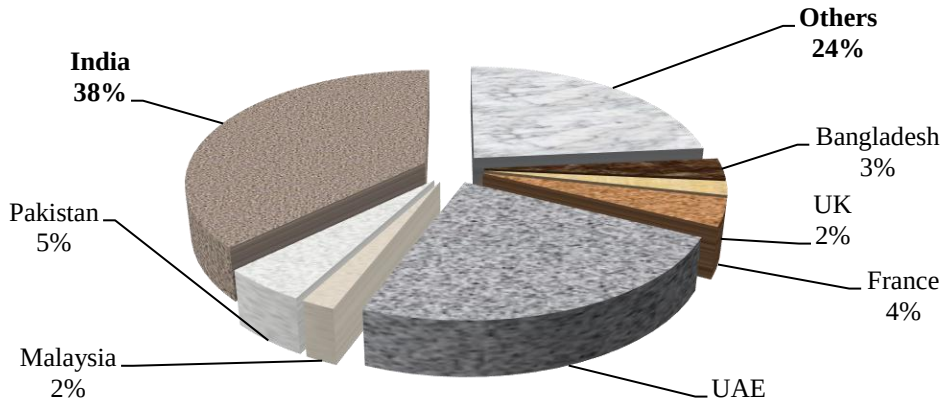
about 60 000 tones by the EC. The palm date trade figures indicate that about 93% of the date harvest is consumed locally and that by far the majority of these palms are not of the well-known export varieties. The world date imports varied greatly over the period 1961 to 2000 (Figure 1).



Source: Adapted from FAOSTAT 2017

Figure 1. World date imports varied greatly over the period 1961 to 2000 (in 000 tons)

The main importers are India, the United Arab Emirates (UAE) and Europe. The top five countries to import dates during 1996-2000 were India, Pakistan, Malaysia, the UAE and the EU (Figure 2).



Source: Adapted from FAOSTAT 2017

Figure 2. Import market share for selected countries (1998 - 2000) in terms of quantity

For the five-year period 1996 to 2000 India imported on average 213 000 tones while the UAE imported 139 000 tones, accounting for 28 percent of the import market. European countries like

France, Germany, the UK and Italy import much more expensive and, hence, higher quality dates. In contrast, countries such as India, the UAE, Malaysia and SADC Region (i.e. South Africa and Kenya) import much cheaper and lower quality dates.

World prices of palm dates

World prices of palm dates varied greatly for different reasons namely the variety, quality, season, type of packaging and market destination. According to the TradStat Trend Report, the average export price per ton in 1996 was in the order of US$3 100 in the case of France (re-export) while Algeria and Tunisia achieved US$3 500 and US$2 600 per ton, respectively (Table 3).

Table (3): Average farm-gate prices for export quality palm dates in 1996 (US$/kg)

Variety	Export price at farm gate (US$/kg)
Medjool	3.5
Barhee	1.5
Deglet Nour	2.5
Hayany	0.6
Iraqi Varieties	0.7

Source: Adapted from TradStat Trend Report; 2017.

Table (3) reflects that one hectare of palm dates of the Medjool variety harvested in season 1996 has attained an average income of $37,800 per annum, based on farm gate-price of $3,500 per ton and an expandable quantity of 10.8 tones/ha.

The marketing of palm dates in European Union (EU)

The European Union (EU) is an important market in terms of value, it considers as the largest date importer in value (over US$100 million in 2000) and the third largest in volume, even though it imports relatively small quantities of dates. France and the UK were the major markets, importing 21 000 tonnes and 10 600 tonnes, respectively (Figures 3 and 4). Compared with over half a million metric tons imported every year in the world, the EU accounts for 10% of the total with some 50,000 tones. However, it accounts for approximately 30% of global date imports in value with a net average of US$85 million per year in 2000 (FAO, 2017).

Imports of dates into the EU are highly seasonal. They tend to take place at the end of the year, for Christmas and New Year's Eve. In 2001, for example, over 80% of EU's imports were made between October and December. This period also corresponds to the date harvest in many supplying countries (Table 4), in particular in North Africa (FAO, 2017). However, imports also vary according to the dates of the Muslim holy month of Ramadan.

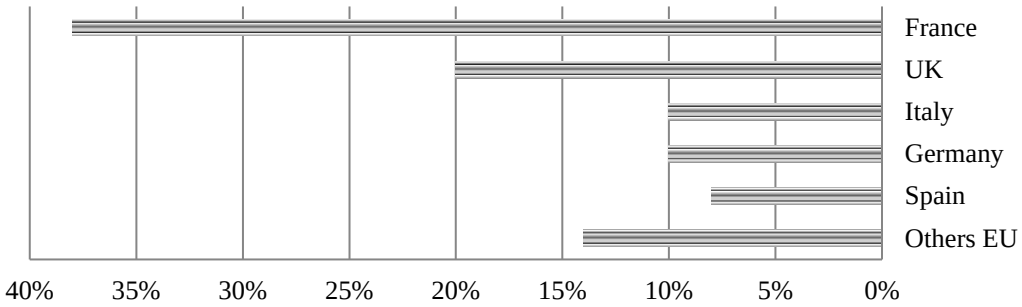


Figure 3. EU gross imports of dates (% volume)

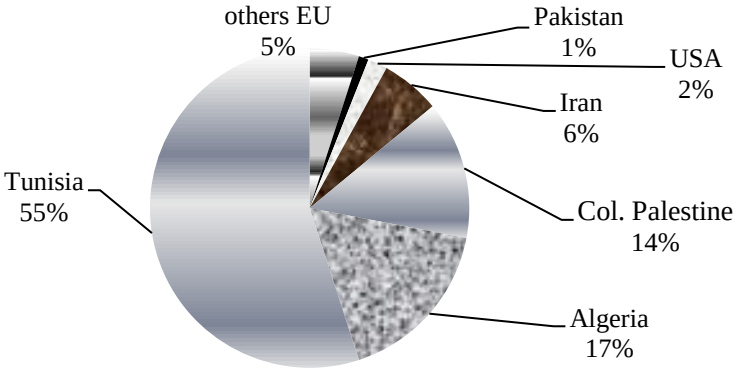


Figure 4. EU imports by origin in 2001 (% volume)

The main consumers of dates in Europe are found in the large and growing Muslim community that mainly consists of people who emigrated from North Africa, South Asia and the Middle East. Karadeniz (2010) reported that the palm dates in Turkey are composing about 40 types and dates are mainly consumed in big cities such as Istanbul, Ankara, Konya, Kayseri and Bursa. The high season of consuming the date palm in Turkey is the pilgrimage period during Ramadan.

The date palm input from Saudi Arabia during the period is legally nearly 800 tons. Additionally, the pilgrims are also thought to bring 6000 tons' palm from Saudi Arabia while coming back to Turkey. Traditionally, date fruits are consumed during Ramadan. The Muslim calendar is based on the moon cycle and therefore the dates of Ramadan vary from year to year.

Table (4): Main supplier of palm dates to EUC (tones)

Supplier country	Production (tones)	Exported amount	EUC imports in value
Tunisia	107,000	27,000	55%
Algeria	370,000	7 000	17%
Col. Palestine	9,500	4,300	14%
Iran	900,000	10,000	6%
USA	16,000	1,000	1.5%
Pakistan	550,000	800	1%

Source: Adapted from FAO' 2001data.

Palm dates export considerations

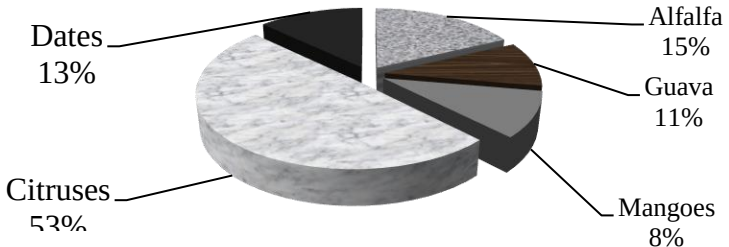
Knowledge of prices, of pricing patterns and the capacity to analyze the economic forces that cause and change those prices will be a necessary condition to help make effective marketing decisions. There is a wide variation in the average export prices achieved by different countries. Higher export prices are achieved by some country such as the colonized Palestine, Tunisia, United States and Algeria, which have developed a specific export strategy (Table 5); to grow top quality varieties and target the higher priced European markets.

Marketing of palm dates in Sudan

Marketing of palm date products in Sudan is still limited by the limitations in domestic markets, whereby the country can raise its date's products for export to international markets to improve market returns and farm incomes, food security and rural development. Trade in dates' products is nevertheless increasing rapidly and it can attain high revenue of hard currency in a short time. Most of Sudanese commodities are well treated before and after harvest and could be sold as high quality products provided the necessary public investment. The world palm dates market is growing at high momentum from one year to another. Palm dates grown for food in Sudan will have a wide-open door in the international market reaching much higher prices and consequently contributing more to the Gross Domestic Product (GDP).

The research depicts the particulars of perennials' production including palm dates in the scheme under study. It illustrates the perennial crops land allocation (Figure 5), yield and production are investigated in Table (6), which also compares farmers' productivities with those of research ones. The dominants perennial crops mix in the scheme mainly comprised citruses, date palms, mangoes, guava and alfalfa fodder.

Figure (5) also illustrates that farmland under perennials was up to 53% occupied by citruses and 15% by alfalfa, while the shares of date palms and guava were 13% and 11%, respectively. Only 8% was accounted to mangoes and considered as the lowest percentage among the perennials combination in the scheme. Research records investigate that dates' yield achieved by El-Ketiab farmers was generally low when compared with research yields attained from research conducted by Sudan's Agricultural Research Corporation (ARC), with a large yield gap reaching 53% as revealed in Table 6. A similar situation applies to other perennial.



Source: field survey by authors

Figure 5. Percent Area Share for Perennials in Area of the Study

Table (5): Main palm dates export considerations

1	Period of production	Production period of dates: e.g. this extends from 30th of August to 30th of Nov for the country. This will allows the markets to be supplied from Sep to May, bearing in mind the possibilities of keeping the product under refrigeration.
2	Logistics	Containers: imports may take place in a number of refrigerated containers with particular number of palletized cartons, as well as collectively by refrigerated truck. Transit time: Determine the period of transit time (2-4 weeks) based on the transportation mean, time of supply and prices (road, sea, air).
3	Sizes	Sizes: mostly three sizes can be offered: jumbo, large and medium (fancy). In the case of the USA, the jumbo size represents approximately 40% of the quantities harvested, the other two sizes representing approximately 30% each
4	Qualities	Qualities: It is difficult to say there is a specific quality standard for all palm dates cultivars (i.e. consumer preference). Mejool as example, it normally has its best degree of maturity and full flavor when it turns dark brown (black), and soft to the touch. There is, moreover, a market for a very mature and very fresh quality of date. In France, some pallets of processed Mejool have been sold and been much appreciated. Generally, Mejool has a light dusty appearance on the surface of the skin.
5	Storage conditions	Storage conditions: some dates cultivars (i.e. Mejool) could be stored under positive refrigeration retains all its qualities for many months (4-6 months). It may also be frozen, which extends its keeping and above all allows the gap between seasons to be bridged.
6	Customs duties	Customs duties: dates from some countries are subject to taxation when they enter the EUC. There is exemption from this tax if the product is imported in order to be repackaged. This is what the British traders do to avoid the charge. They import Mejool dates in 15 lb. cartons of loose dates and repackage them using their customers' trademark.
7	Loose packaging	Loose packaging**:** packaging intended for re-packers is generally 5 kg or 15 lb. That intended for loose sale is 5 kg. It is generally packaging which is very carefully produced using quality kraft material and sufficient thickness to avoid any sagging. The carton is generally telescopic with a printed lid which may, serve as a display. The bottom is of the same quality as the lid. It is covered with a film which protects the dates and has a cardboard divider which prevents the fruit from being compressed in the course of handling.
8	Individual packaging	Individual packaging**:** only UK, through large-scale retailers, has so far succeeded in getting a small package onto the market. In Germany, trials with a 150-g pack were under way in 2000. In France, a 250-g window box is selling sluggishly.
9	Prices	Dates prices**:** prices vary depending on the origin, the manufacturer, the size and the means of transport.
10	Limits on the development	High price: the low productivity of some dates types. The direct consequence of this small volume of supply is the high price of the product. Large-scale retailers: The willingness of large-scale retailers to invest in certain types of dates. These dates should be accessible to consumers as a whole, it is essential that it should be available in the departments of large hypermarkets and supermarkets. While this appears to be the case in UK, not in other countries.

Source: Adapted from FAO' 2001data.

Table (6): Distribution of surveyed tenancies and production of perennials

Crop	Average Area (fed)	Percent Area Share	Yield (kg/fed)	Production (kg)	ARC yield (kg/fed)	Yield Gap %
Dates	1.23	12.3	3000	3690	6500	53

Source: field survey by authors

Table (6) indicates high potential to improve dates' fruit productivity in area of the study as reflected by the notably higher research yields as compared to farmers' ones. Gaps and differences in crop productivity not only indicate differences in crop production technology, but also differences in crop varieties.

The paper has revealed that numerous hindrances are affecting the marketable surplus of palm date in Sudan. Productivity of dates is still under potential of the research and standard ones, agricultural resources implying irrigation water and farmland availability are in shortage. Varietal improvement in the country is constrained by shortage in tissue cultured date palms while appropriate preservation technology is lacking. Palm dates in Sudan fetch poor and volatile prices and their sale market prospects are rather narrow, being further influenced by high transportation cost, shortage and high cost of labour. Needed inputs such as improved seedlings and agro-chemicals are scarce and expensive. Further, the palm date fruit are attacked from time to time by various insects and diseases, e.g., palms green scale insect, the termite, the white scale, Targ, and a number of store pests. Furthermore, date production also suffers from the high irrigation water cost rate and lack of financial capital.

The main markets of the scheme tenants

In Sudan, the marketing of palm dates is one of the important factors constraining dates production. Palm date yield improvement, date quality and cultivar, processing and marketing facing numerous challenges to meet consumer expectations as well as international trade standards. Elfeil (1993) mentioned that the marketing of crops in the northern region is characterized by being deprived of government involvement; hence dates marketing are the responsibility of growers who undertake it individually. The product is usually sold immediately after harvest at unfavorably low farm gate prices. The causes that enforce farmers to sell immediately after harvest are the need for cash along with the small farm products that are too small to be transported to urban markets. The main characteristics of the markets in north Sudan are that the prices are usually less than in big city markets. However, local markets are periodical, which provide opportunities for the exchange of different goods among actors who came from different neighboring districts.

The research observed that there are no fixed primary markets for palm dates fruit in the north region of the country except for some weekly markets held at different rural places scattered among the region, each on a particular day. Accordingly, the main markets for the marketable surplus of palm dates in the states are RNS weekly market. The main actors of these markets are public scheme tenants, villages' traders and wholesalers. The general characteristics

of north Sudan markets are that the prices are always less than the capital and other regional centers market prices. In addition, they are periodical markets which provide opportunity for the exchange of a variety of commodities among market actors who come from different neighboring villages. Generally, the research analysis revealed that more than 50% of El-Ketiab palm dates growers prefer to sell their crop in the near markets at a distance of about 30-50 km, while the majority (46%) of them procured their crops for the capital of the country in Khartoum cities markets by crossing about 250 km as depicted in Table 7, it also shows the main perennial crops markets in the study area (Table 7).

Table (7): The main markets of palm dates in area of the study

Market	Number	%
Elketiab	15	30
Farm gate	05	10
Elzeidab	06	12
Shendi	01	02
Khartoum	23	46
Total	50	100

Source: field survey by authors

Table (7) further illustrates the distribution of El-Ketiab surveyed farmers transacting in these weekly markets. The study results revealed that 54% of the tenants procured their harvested palm dates to the small scattered village markets of River Nile State, allocated at El-Ketiab market 30% followed by Elzeidab at 10%, while farm gate and Shendi markets received about 12% and 2%, respectively, and Khartoum were found to be only 46% for each.

The analysis found that more than 50% of the scheme tenants prefer to sell their crops in nearest markets, while 46% of them take their crops to big city markets such as Khartoum market about 250-500 km away. The study also showed that most of tradable palm date crop (56%) was traded in mixed markets around the area of the study, followed by 20% transacted in town markets 12% offered at the farm gate and 8% was brought to village markets. The share of village traders who usually play the role of money lenders to the tenants was found to be 4%.

Distribution of palm date crop quantities

Perennial crops – especially citruses, palm dates, mangoes, guava and alfalfa fodder – are generally considered as the main sources of cash and food crops. In addition, they play an essential role in sustaining and developing the production of the farming systems.

Tenants' decisions on marketable surplus quantities and the timing of their sale depend on the type of crop, supply, demand and their prices. In spite of the fact that dates producers in Sudan exert great efforts during the growing season, hoping for profitable harvests, they face low-price shocks. Accordingly, and due to lack of public investment and the inadequate marketing infrastructures, they are usually compelled to sell major quantities of their crops immediately after harvest at unfavorable prices, and allocate the remaining portion to future sales as shown in Table 8.

Table (8): Distribution of the palm dates disposal quantities in the study area

Crop Production	Production (kg/fed)	Post-harvest sale (kg)	Gifts & H.H. consumption	Future sale (kg)
Date	3690	2030	554	1107
%	100	55	15	30

Source: The field survey by authors

The field survey results denoted that the allocation of marketable surplus to sales at different times, after allocating a portion to household consumption, gifts and others, depends on crop prices. As illustrated in Table (8), palm dates growers store the crop in their house yard or in traditional stores for many months waiting for prices to increase. The dates farmers reported that 45% (554+1661) of their date's production go for storage for future sales and household consumption. About 86% of the palm dates fruit was sold (48% immediately after harvest and 39% for future sales), with the remaining 13% going to storage. As a dominant phenomenon in the northern states markets, palm dates and pulses are partly sold after harvest and partly stored, while vegetables, tomatoes and potatoes are sold immediately post-harvest due to lack of appropriate storage infrastructure and inadequate markets as illustrated in Figure (6).

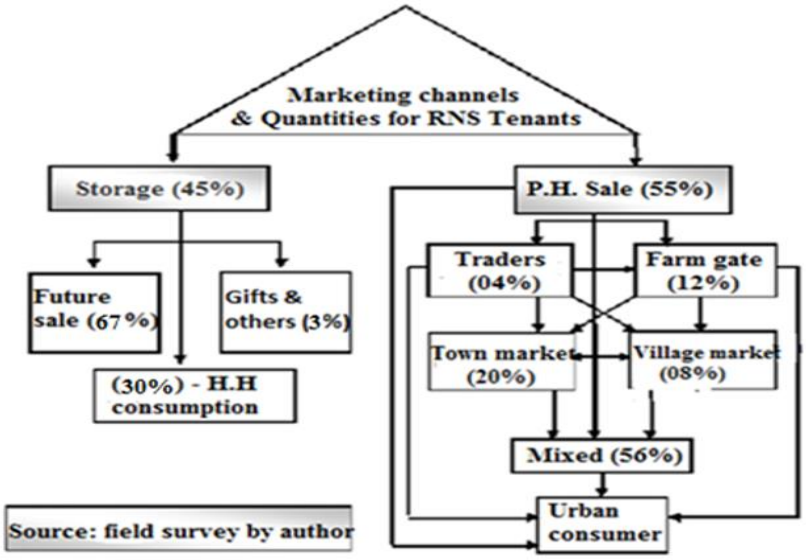


Figure 6. Palm dates marketing channels and quantities allocation in north Sudan

Marketing information

The study observed that development in communication means has become an essential approach for marketable surpluses where they can reduce marketing cost as well as raising farmers' awareness about urban markets. The date palm growers in the area of the study reported that they depend on mixed sources of market information such as local markets, traders, and agricultural officers of the scheme. In the last decade, north Sudan witnessed improvements in agricultural products marketing due to some progress in its public investment. The adequate infrastructure in the region has contributed to some extend facilitating fruit and cereal crops transportation and

marketing. Although, there are numerous linkages and options for marketing of dates, but still the crop growers face some difficulties to undertake the right decision of where and when to sell their product. The hesitancy of northern States farmers might be attributed to the high cost and difficulties of transportation and its high cost, in addition to different fees and charges levied along the roads from rural areas to the entrances of big cities markets. Furthermore, the still poor marketing infrastructure is considered as a chronic hindrance facing date growers in northern region of Sudan to diversify their markets.

Palm dates producers in north Sudan lack adequate market records, validity of information and are randomly market their dates individually not as one body to control the supply and demand of their crop marketable surplus. The study observed that public investment in north region of Sudan improved the means of communications where highways and other infrastructures contributed to reducing the marketing expenses, alleviating lack of knowledge risk of the right information on prices in urban and village markets, awareness regarding supply and demand, and saving the time of farmers. But the middlemen and brokers still play their historical role between the date farmers, retailers and consumers, a situation leading to decrease in the returns to dates growers.

Table (9): Source of marketing information in North Sudan

Source	Frequency	Percentage
Markets	20	40
Communications	03	06
Wholesale merchant	04	08
Mixed	23	46
Total	50	100

Source: field survey by authors

Table (9) shows that 46% of the surveyed tenants depend on mixed or diversified sources as the main sources for markets information, followed by markets sources at 40%, while 8% of the surveyed tenants depend on wholesalers and only 4% depends on communications.

Analysis of palm dates returns

Since palm dates farming are contributing significantly to the agricultural sector, the aim should imply its development and dissemination in the Sudan. The partial budget is an efficient tool for large and small firms; it helps farm managers to estimate the financial effect of incremental changes and only implies changeable resources. In other words, only the change under consideration is evaluated for its ability to increase or decrease income in the farm business. Elsir (1997) mentioned that partial budgeting can be useful in the decision process farm owners and managers use to decide on alternative uses of resources they have in their businesses. Partial budgeting is a systematic approach that can assist the manager in making informed decisions. But this budgeting process can only estimate possible financial impacts, not assure them. Management decisions and chance can change the projections. These may result in better or poorer than expected performance. Repeating the analysis using different assumptions about key

variables will give some idea about the degree of risk involved in making the proposed change. Many studies mentioned that partial budgeting methods continue to be the backbone of much of analysis on agricultural policy. In their simplest form, budgets provide the evidence that policy makers use to make decisions about private profitability and hence the incentives that farmers have to grow particular commodities. The basic data used to calculate gross returns per feddan are output value (crop prices times' quantity of output, i.e. yield per feddan) from which average total variable cost are deduced to get gross margin per feddan.

Gross margins

Gross margin is a useful indicator of how profitable a farm is at the most fundamental level. Gross margins unveil how much a firm earns to pay fronts fixed costs. Firms with higher returns or gross margins will have more money left over to spend on other activities such as updating technologies, land investment, improvement of farming system. The general mathematical form for the gross margin (GM) calculation per crop is as follow:

$$GM = GR - TVC$$

Where:

GM: Crop gross margin per fed in SDG;

GR: Crop gross revenue per fed in SDG and

TVC: Crop total variable costs per fed in SDG.

Fortunately, the global demand for dates is annually increasing due to consumers' awareness of their value and benefits. Babiker (2003) reported that, Sudan exported 20 plant and livestock food products as conventionally cultivated foods valued at US$305.7 million. In Sudan, in view of the current oversupply of conventional dates on the local markets, of the low level of prices and of the tendency of consumers to shift towards higher quality products or other promising varieties, there seems to be little scope for a large increase in producing of conventional dates to these markets. The profitability of conventional date products for a newcomer would be very low, even with low production costs. Of all conventional date palm cultivars, the Barakawi was the most preferred. The cultivars diversification in north Sudan might be due to more than one factor such as geographic location, climatic zone, date usage, farmer knowledge, education level, extension services, date palm returns, family size and research innovation. In order to improve date prices, dates growers of "non-traditional varieties" (Sukary, Majdool, Khadry, Barhy…ect.) would have to invest in promotion and advertising campaigns to convince consumers to switch from conventional dates to the mentioned new varieties. In this case, the markets that should be targeted are Sudanese big cities, and regional and international markets, as consumption of conventional dates is still relatively high there compared to new varieties. Using basic research data, the gross margins for dates under study were assessed individually per feddan and the results were expressed in Sudanese Pound (SDG) as discerned in Table (10).

Table 10: Gross margin analysis for palm dates fruit (SDG/fed)

Budget Component		Value
Cost of production	**(SDG/fed)**	**1,900.8**
Average yield	(kg/fed)	3000
Average price	(SDG/kg)	6.67
Gross returns	**(SDG)**	**20,010**
Gross margins	**(SDG)**	**1,002.0**

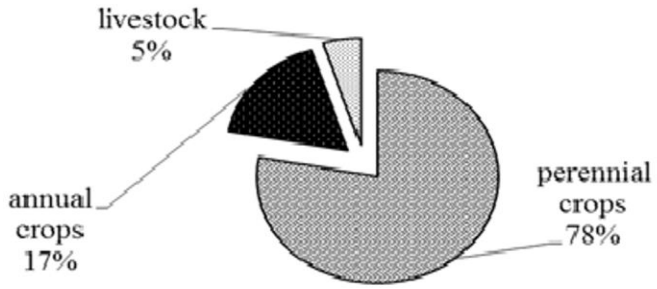
Source: calculated by the researchers

Table (10) illustrates that the GM of dates were positive, and the crop described as a low gross margins. The low returns of dates indicate for their low yields, with yield improvement and adoption of high quality cultivars of dates, higher gross margins can be obtained. In general, expenses are lower than gross returns. Dates price vary between during the year and among varieties over time. On the other hand, palm dates production is changing rapidly, leading to price instability. For example, high prices for non-conventional varieties can lead many tenants to grow these verities, which might depress prices. Thus, tenants' awareness is important about marketing process within the promise offered by non-conventional cultivars. Generally, the awareness of date growers and consumers' preferences and demand for different date cultivars are important for planning and designing a sustainable genetic resources conservation strategy, but do not often receive much attention in Sudan.

Main income sources of palm dates growers

No doubt farm income diversification is considered as useful tool to combat agricultural risk as well as for farm sustainability. Beetz (2002) reported that, integrating trees and shrubs with the other enterprises on a farm can create additional sources of income, spread farm labor throughout the year, and increase the productivity of the other enterprises, while protecting soil, water, and wildlife. As well, enterprise diversification makes it easier for farms to be more self-sufficient in terms of nutrients, livestock feed, soil organic matter and energy. The palm date crop is playing an important role in the culture in north Sudan as well as contributes to livelihoods of rural people. Babiker (2003) found that the expected higher income for palm dates growers will also be positively reflected on their standard of living. More national revenue means more money available for solving related problems that hinder rural development. Marketing large amounts of palm dates will make the country a prominent figure in the international market of dates' products. It will also attract global investors to invest in agricultural production of the crop. The most common source of tenants' farm income is the sale of harvested field crops and livestock. Also, off-farm income is still one of the fundamental sources for the scheme tenants to meet the farm operation cost and household expenditures. The research revealed that the main off-farm sources in the area are remittances and contributions of family members, formal employment, trade, and other off-farm private activities. About 37% of the tenants earned off-farm income beside their farm income, while 63% relied only on farm returns. Most of the farm income accrues from palm dates and other perennials (78%). The majority of tenants (63%) diversified

by growing several crops at one time, often having both livestock and annual crops, and sometimes value-adding enterprises (Figure 7).



Source: field survey by auth**ors**

Figure 7. Farm income sources in area of the study

Figure (7) shows that farm income is obtained mainly from three sources: perennials which providing the highest farm returns followed by annual crops, and 5% gained from livestock as the lowest source. This information ensures the importance of perennial crops in shaping the tenants' returns in the State.

Conclusion and policy implication

The research established that Sudan boasts of high potential to promote the palm date productivity due to many comparative advantages particularly in El-Ketiab scheme, namely availability of stable and high quality agricultural resources, suitable environmental conditions, huge experiences of date palms growers, and the strategic location of the target area for palm date's investment. Although the current situation under the prevailing yields and prices is not in favor of palm date's investment but the potential looks promising. Thus government interventions and application of suitable policies are critical to provide incentives to the palm dates producers in the country by giving momentum to address the prerequisites of dates exportation, technology transfer, international collaboration, highlight priorities to address major hindrances for facilitating date palm marketing and date palm growing network, these solutions will ease to achieve dates farming sustainability and formulating relevant policies that provide reasonable and stable prices to dates producers.

Further, it is essential also to consider that proper management of palm dates farms production, handling, improvement of marketing strategies and processing implying cool storages and modern transportation as fundamental for sustainable palm date farms in Sudan. This should also be supported by encouraging private funding and professional investors in date products marketing to ease the State's responsibility and promote date farms in the country. Nevertheless, public investment is needed to improve palm date production and marketing. Vitally and important is the need for reviving the marketing system in area of the study and make strong links with national and international markets. Equally important is the maximization of use of the available agricultural resources for producing high quality cultivars of dates, exchange of

germplasm and conservation, setting up of in vitro culture labs for improving date crop combined with the other perennials combination.

Lastly, the conventional farming system of dates and the low quality of many of the grown date varieties will need to be addressed by gradually shifting to high-quality dates and accordingly provide incentives to make this crop more profitable due to its importance for malnutrition and farmers' livelihood.

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Toxicity of Ethanolic Extract of Leaves of *Calotropis procera* Aiton (Ushar) (Gentianales: Apocynaceae) Against the Larvae of *Culex quinquefasciatus* Say (Diptera: Culicidae)

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Abstract

The *Calotropis procera* plant (Ushar) which is used in this study, is available in nature, and considered as a promising resource of larvicide. The objectives of this study are to evaluate $LC_{50\%}$ and $LC_{90\%}$ values under laboratory condition after exposure (for 24, 48 and 72 hours) of ethanolic extract of *C. procera* (Ushar) leaves against the larvae of *Cx. quinquefasciatus.* The LC_{50} values (50% mortality) were 360 and 198 ppm for 24 and 48 or 72 hours of exposure, respectively. The LC_{90} values (90% mortality) were estimated to be 881ppm at 24 hours and 479 ppm for 24 and 48 or 72 hours of exposure to *C. procera* leaves extract.

***Keyword*:** *Calotropis procera*, *Culex quinquefasciatus*, larvae, Toxicity

سمية المستخلص الإيثيلي لأوراق نبات العشر *C. procera* ضد يرقات بعوضة الكيولكس خماسية الخطوط

طه منصور الحاج حمد

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المستخلص

نبات العشر *Calotropis procera* المستخدم في هده الدراسة متوفر في الطبيعة ويعد من المصادر الواعدة للمبيدات اليرقية .هدفت هذه الدراسة لتقييم سمية المستخلص الإيثيلي لأوراق نبات العشر *C. procera* ضد يرقات بعوضة الكيولكس خماسية الخطوط *Culex quinquefasciatus* في ظروف المعمل. عُبِر عن السمية هنا بـLC_{50} (التركيز الذي يقتل 50% من اليرقات) وLC_{90} (التركيز الذي يقتل 90% من اليرقات). كانت قيم LC_{50} و LC_{90} محسوبة بالجزء من المليون ppm للمستخلص الإيثيلي لأوراق العُشر *C. procera* (LC_{50} =360 and 198 ppm; LC_{90} =881 and 479 ppm)بعد فترة تعرض لمدة 24و48 أو 72 ساعة في ظروف المعمل علي الترتيب.

كلمات مفتاحية: نبات العشر، بعوضة الكيولكس خماسية الخطوط، اليرقات، السمية

Introduction

Culex quinquefasiatus (mosquito) is of cosmopolitan distribution, and it transmits human filariasis a major public health problem in many tropical countries including Sudan, it infects more than two million individual worlds annually (Gosh *et al*., 2008). The adult females have anthropophilic and zoophilic tendencies. It is a potential vector of *Dirofilaria immitis* and arboviruses like West Nile virus (WNV), Rift Valley fever virus, avian pox and protozoa like *Plasmodium relictum* that causes bird malaria and Chikungunya virus (Bhattacharya and Basu, 2016). El-Rayah (2007) reviewed that about 45 species of *Culex* mosquitos are recorded by Lewis (1954) in Sudan including the old name of *Cx. quinquefasciatus* (*Cx. pipiens fatigans* Wiedman). The *Cx. quinquefasciatus* is also known as domestic annoying mosquito especially in urban areas. It is the most prominent species of mosquitoes group in Khartoum, and Sudan (El-Rayah, 2007). The control of *Culex* is normally based on the prevention of breeding. Since such intervention is impossible or economically unfeasible, larvicides can be used (Rozendaal, 1997). Larval stages of mosquitoes are targeted in control strategies, because the larva is relatively immobile, and more concentrated than the adult stage (Karunamoorthi *et al*, 2008; Ali and EL-Rabaa, 2010). Synthetic insecticides pose a high residual toxicity which poison live-stock and human beings (Karunamoorthi *et al*., 2008). Consequently, researchers are currently investigating various plant extracts to be used as insecticides for controlling larvae of mosquitoes, as they are suspected to be environment friendly, biodegradable, and safer than synthetic larvicides (Cetin *et al*., 2006).

More than 2000 plants are known to possess larvicidal activity in their secondary metabolite compounds of plants, such as saponin (Wiesman and Chapagain, 2006), phenolics, isoflavonoids, essential oils, alkaloids, and tannin (Gosh *et al.*, 2008). Phytochemicals may serve as a suitable alternative to synthetic insecticides. In Sudan, Ali (1987) reported larvicidal activity of *Calotropis procera* (*Usher*). Many plants extracts are applied as a phyto-control of mosquito's larvae such as *C. procera*, a common semi desert weed which are widely distributed in Sudan (Ali and EL- Rabaa, 2010)

The objectives of this study are to evaluate toxicity effect represented as $LC_{50\%}$ and $LC_{90\%}$ values under laboratory condition of ethanolic extract of *C. procera* (Uschar) leaves against the larvae of *Cx. quinquefasciatus.*

Materials and methods

Mosquito rearing

Egg rafts of *Culex* mosquitoes were collected from their breeding sites, and then transported to the laboratory into plastic vials (7cm in diameter and 7cm deep) containing de-chlorinated (three days old) tap water; Under, such conditions hatching takes place after approximately 24 to 48 hours. The larvae were kept in clean plastic container containing distilled water; they were fed on autoclaved wheat flour. Pupae were transferred in small plastic cups and kept into mosquito breeding cages 60 × 60 × 60 cm. High relative humidity was ensured inside the cage (60±10%) by means of a wet towel fixed over the top of cage. The cage was provided with a wick containing 10 percent sucrose for male. Females were given the chance to feed on blood of a back plucked pigeon once daily (Elhag, 2010). To guarantee genetic homogeneity, all larvae used in the present investigation were older than the fourth filial generation (F4).

Collection and preparation of plants materials

Fresh, healthy, leaves of the Ushar *C. procera* were clipped from wild growth populations surrounding of the Faculty of Education, Nile Valley University during November-2018, and transported to the laboratory, washed, plotted in newspapers, and left for two weeks to dry in the shade. The dry leaves were powdered and sieved, and kept in plastic bags until needed (Tahir *et al*., 2013).

Extraction of plants materials

Extractions of substances from the dry leaves were done using absolute ethanol (analytical grade). When needed, about 50 grams of the dry leaves were mixed with 300 ml ethanol. The blend was kept cold for a week in a refrigerator. The solution was then filtered with muslin cloth first and then by filter paper, filtrate was kept in a previously weighed 500 ml glass beaker. The solvent was completely evaporated in water bath (70^0C) as described by Elimam (2007); Elhag (2010) and Shahi *et al*. (2010). The thick pasty extracts were left in a coverless beaker at room temperature (30 ± 5^0C) to get a dry extract. A strict weighing procedure with a digital balance

accurate to the fourth decimal was followed to determine the amount of dry extract obtained from a known weight of dry leaves.

Preparation of stock solutions of the plant extracts

Stock solutions were prepared from crude extract dry materials by adding a suitable amount of distilled water to yield a known concentration 1% (*w/v*), thus 10000 parts per million (ppm). The prepared mixtures were kept in an airtight brown vial as stock solution and refrigerated until used for bioassays to prepare the test concentrations. The following simple equation was used to determine the total volume of distilled water needed to obtain the required concentration of the stock solution:

$$S = (D \times 100)/ C$$

Where:
S: the required ml of distilled water; *D*: dry weight of plants materials extract in grams or volume of latex; *C*: concentration of stock solution required (%).

Bioassay for larvicidal activity

Following the conventional methods recommended by WHO (2005), five concentrations (5000 ppm, 2500 ppm, 1250 ppm, 620 ppm and 310 ppm) of plant extract were used to catch a trend rundown mortality between 0 % to 100% in mosquito larvae. Every concentration was tested with a total of 100 late third instars laboratory reared larvae executed as five replicates, each with 20 larvae. The tests were done in 200 ml glass jar containing 50 ml of the test solution. The control was set up with 50 ml of distilled water. The test larvae were not fed during the test. Mortality was recorded after 24, 48, and 72 hours for each concentration.

Statistical analysis

To find out whether the applied doses of toxicants are mathematically related to the intensity of response and to evaluate the strength of the relationship, the quantitative data obtained were subjected to Pearson correlation analysis (R Coefficient correlation). The concentration and mortality percentage were found to form a linear relationship. The regression equation ($y = a + bx$) was calculated by regression analysis. LC_{50}, LC_{90} and 95% confidence limits intervals were calculated from a log dosage-probit mortality equation (A double transformation regression probit analysis).

Results

Correlation between the concentrations of the tested plants extracts and the mortality response of *Culex quinquefasciatus* larvae

The Pearson's correlation R analysis of results showed the presence of high significantly positive correlation between concentrations of plant extract and mortality responses. The results showed concentration dependency, as concentration increased, percentage mortality increased. High

positive significance Pearson's correlation has been detected between concentrations of ethanolic extract of *C. procera* leaves and mortality responses of the larvae of *Cx. quinquefasciatus* at 0.998, 0.864, and0.864 for 24, 48 and 72 hours of exposure under laboratory conditions, respectively (Table 1 and Figure 1).

Toxicity of ethanolic extract of *Calotropis procera* (Ushar) leaves against the larvae of *Culex quinquefasciatus* under laboratory conditions

The extract possesses high level of toxicity against the larvae of mosquitoes *Cx. quinquefasciatus*. The LC_{50} values (50% mortality) were 360 and 198 ppm for 24 and 48 or 72 hours of exposure, respectively. The LC_{90} values (90% mortality) were estimated to be 881ppm at 24 hours and 479 ppm for 24 and 48 or 72 hours of exposure. Among the three time of exposure for the two tested form it was observed that, 72 hours of exposure was gained the lowest LC_{50}, and LC_{90} value; while 48 hours of exposure comes second followed by 24 hours of exposure (Table 1 and Figure 1).

Discussion

Although chemical control is an effective control for pests because it is practical and rapid in action, but the uses of synthetic insecticides has led to environmental pollution it has many disadvantages such as residual effects, and they also kill non- targeted insects. Mosquitoes also showed resistance to the insecticides with passage of time (Khan *et al.,* 2015). The plant used in this study *C. procera* is promising natural source of larvicides, it is simple and safe to the layman, not hazardous to the environment, and biodegradable (Olofintoye *et al.,* 2011).

The statistical analysis of the results obtained in the present study showed dose dependency, as concentration of extract increased, mortality of mosquito larvae increased. The leaves extracts of the milkweed *C. procera* show oviposition deterrant, larvicidal and ovicidal activities against mosquito (Girdhar and Pkarnd, 1984; Singh *et al.,* 2005; Sripongpun, 2008 and Kabir *et al.,* 2010).

Table (1): Correlation between different concentrations of *Calotropis procera* (Ushar) leaves extract and mortality of *Culex quinquefasciatus* larvae under laboratory conditions.

Duration of exposure /hours	Lethality /ppm (95% Confidence interval)		R	Sig
	LC_{50}	LC_{90}		
24	360 (230- 490)	881 (760- 1002)	0.998	0.095
48	198 (000- 396)	479 (361- 597)	0.864	0.155
72	198 (000- 396)	479 (361- 597)	0.845	0.155

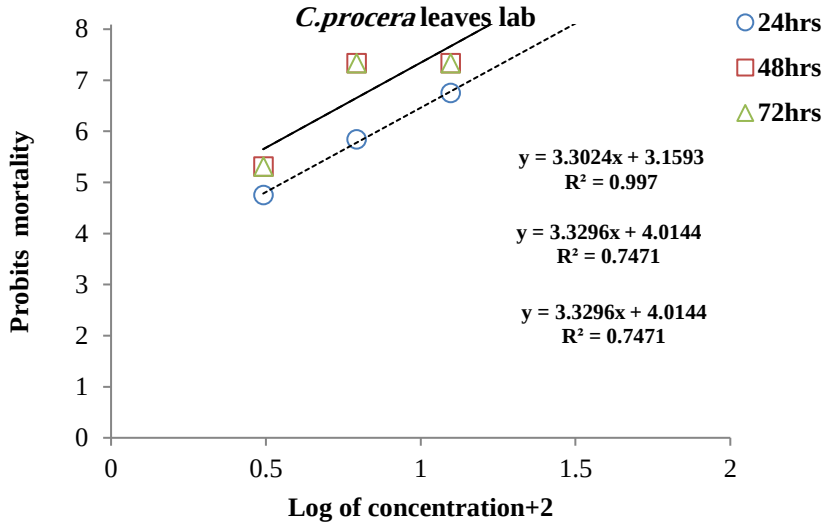

Figure 1. Concentration /response regression line of ethanolic extract of *C. procera* (Ushar) leaves against *Culex quinquefasciatus* larvae

In general, the present results showed time dependency, as duration of exposure increased, mortality of mosquito larvae increased. It can be observed that, 72 hours of exposure gave the lowest LC_{50}, value; while 48 hours of exposure comes second followed by 24 hours of exposure. This agreed with the findings of Singh *et al*. (2015) who noticed that, the toxicity potential of the *C. procera* leaf extract has increased after prolonged periods of exposure of the larvae of *Aedes aegypti*, the LC50 decreased by 2.3%. The influence of exposure time on larval mortality may be due to the amount of active ingredients consumed. The results coincided with those of Elimam (2007), who found that the LC_{50} values in the case of *C. procera* leaf were 187.93, 218.27 and 264.85 ppm for 2nd, 3rd and 4th instars larvae of *Cx. Quinquefasciatus*, respectively. The LC_{90} values (90% mortality) were shown at 433.51, 538.27 and 769.13 ppm for 2nd, 3rd and 4th instars larvae, respectively of *Cx. quinquefasciatus*. The results are in conformity with that reported by Kumar *et al*. (2012) who obtained LC_{50} values of 137.9 ppm against *Culex gelidus* and 110.05 ppm against *Cx. triataeniorhynchus* when assayed with aqueous extract of *Calotropis gigantica*. However, results disagreed with those of Osman (2003) who found LC_{50} of 0.929 g/L of Usher leaves water extract against the larvae of *Culex*, and those of Ali (2004), who obtained LD_{50} of 122.29 mg/L for *Culex* larvae. Singh *et al.* (2015), found that, *C. procera* leaves hexane extract LC50 and LC90 values were 78.39 and 100.60ppm, respectively when conducted against *Aedes aegypti* larvae. Further, Usher leaf water extract LC_{50} recorded 108 mg/l by Hag El Tayeb *et al*. (2009). The effects of ingestion in poisoning of larvae, is in consistent with the results of Elimam (2007) who revealed that a non-feeding pupal stage was not affected till a concentration of 10000 ppm of *C. procera* extract.

From the results of this study it can be concluded that ethanolic extracts of *Calotropis procera* possess good larvicidal activity against *Culex quinquefasciatus* larvae and considered as a promising source of larvicides, because it is available in nature, its application is simple and safe to the layman not hazardous to the environment, cheap, and biodegradable. Larval sites of

Cx. quinquefasciatus are well known to be frequently heavily polluted, and it is important to know whether a larvicide is efficient in laboratory and would be feasible in polluted water which needs further studies.

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