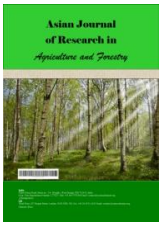

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Impact of Cultural Practice, Socio-economic Level and Environment on the Profitability of the Date Palm (*Phoenix dactylifera* L.) in Niger (West Africa)

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Authors' contributions

This work was carried out in collaboration among all authors. Author MLAI designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors OZ and MMI managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Phoeniciculture, or date palm cultivation plays a major socio-economic and ecological role. However, few studies have quantified the drivers of date palm cultivation and its socio-economic and environmental benefits in West African Sahel. Therefore, this study assessed the effect of anthropic and environmental factors on quantitative and qualitative production of dates palm in Niger. We conducted an ethnobotanical survey to collect data in the Sahelian and Saharian zones of Niger. We used permutation regression test to assess the influence of climatic conditions, fidelity

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of cultural practices implementation and the socio-economic level of producers on the date palm profitability. The Spearman rank correlation coefficients between the economic parameters and the geographical position of palm groves were also estimated based on the Spearman rank permutation test. A total of 60 producers were surveyed in ten villages of Sahelian and Saharian zones known as two main phoenicicultural areas in Niger. This analysis showed that date palm production varies quantitatively and qualitatively across agro-ecological zones. The study revealed also that ethnic groups influence the quantitative aspect of date palm production (P = 0.023), by socioeconomic parameters (P = 0.005) and by the index of fidelity to the cultural practice implementation (P = 0.035). The date palm production varies quantitatively (P = 0.001) and qualitatively (P = 0.033) according to the agro-climatic zones. The Spearman rank test shows a significant correlation between the quantitative and qualitative production, the geographical position of the palm groves and the depth of the water table. The profitability of the date palm seems not to be up to the phoenicicultural potential that can be the consequence of the poor implementation of the cultural practices, the socio-economic level of the producers and the environmental conditions.

Keywords: Date palm; phoeniciculture; profitability; cultural practice; socioeconomic level; environment; Niger.

1. INTRODUCTION

The date palm (*Phoenix dactylifera* L.) is a tree monocot of the *Arecaceae* family that has been cultivated for several millennia in the Middle East and North Africa [1,2,3]. The archaeological remains found in the Middle East showed that the date palm cultivation was from the end of the 4th millennium BC [4]. Phoeniciculture represents the agriculture pillar in the sub-Saharian Africa oasis while date palm is the emblematic tree in Saharian and Sahelian regions which are considered as hotspots of climate change associated with great social and environmental vulnerability [5]. Date palm has a high ecological, economic and social value in the world. As a multipurpose species, it provides very nutritious dates when consumed fresh, dried or processed products (syrup, dough, flour). The dates are also used for animal feed [1]. The Saharan and Sahelian populations are also using date palm in many socio-economic activities including handicrafts, basketry and the fight against silting up. This fruit contains high percentage of carbohydrate, dietary fibre, antioxidants, and minerals, contain all essential amino acids and variety of B-complex vitamins and vitamin A [6,7,8]. The date palm trees are also essential in oasis agrosystems as they create cooler and humid local climatic conditions which are conducive to the cultivation of others fruit trees, cereals or legumes [9,10]. In Pakistan, the date sales contributed more than 50% to the total income of 39% of household and up to 90-100% to 24% of household [11]. Although date palm has high socio-economic importance worldwide, it is under-exploited in Niger. Thus, to contribute in improving the living conditions of the local populations in the phoenicicultural zones of Niger, good knowledge of the anthropic and environmental factors influencing the profitability of the date palm are required. Date palm profitability was largely investigated [12,13,14]. However, as far as we know, the effect of farming practices implementation, the date palm producers index of socio-economic level and the agro-climatic zones profitability have not studied notably for Niger. The study hypnotized that cultural practices, the socio economic level of producers and the agro-climatic zone influence the benefits of date production in Niger. Therefore; this study aims to investigate the key parameters influencing date palm productivity and profitability in Saharan and Sahelian regions of Niger for (i) assessing the cultural practices implementation index effect, (ii) evaluating the index of producer socio-economic level and the environment effect on date palm profitability, and (iii) estimating the correlation between the economic and ecological parameters of the palm groves (longitude, latitude, altitude, depth of the water table).

2. METHODOLOGY

2.1 Study Area

In Niger, date palm is cultivated in two zones, the traditional zone in the Sahara and the marginal zone in the Sahelian area. The traditional zone extends to the north and north-east in Agadez region and the marginal zone extends to the south-east in Manga and Damagaram located respectively in Diffa and Zinder regions [15]. The study area of this study are the Saharan zone (latitude 18°05'N to 19°07'N; longitude 12°55'E to

12°55'E) and Sahelian zone (latitude 13°20'N to 13° 55'N; longitude 9° 50'E to 11° 50'E) (Fig. 1). These areas are characterized by an arid climate with rainfall less than 150 although in Aïr zone the rainfall can be 200 mm with high and extreme contrasted temperatures, very low relative humidity and extreme irregular precipitation [16]. Sahara is a desert where vegetation appears only in humid depressions and oasis. The vegetation is steppes of arid climates, notably the grassy steppe with Acacia of loose cover composed by thorny xerophyte plants and grasses [17]. The population main activities are livestock (goats and camels). In this area, irrigated agriculture, mainly phoeniciculture and market gardening, due to microclimate induced by the date palm, is conducted in oasis and represents an important source of income [17]. In the Sahelian area, the rainfall is 350 to 600 mm [16] (Fig. 1). The ecosystems of this area are characteristic of transition zones. The vegetation is shrubby or tree savannahs with different recovery rates. Both rainfed and irrigated agriculture are conducted in Sahelian zone. Cereals are largely cultivated, but cash crops and market gardening are an important part of household income sources. Livestock farming is widespread and strongly mixed with agriculture as agro-pastoralism [17] the Sahelian zone.

2.2 Samples and Data Collection

The samples are palm groves in Aïr, Ingall, Kaouar, Agram and Djado locations from Agadez region (Saharan zone) and Manga and Damagaram locations of respectively Diffa and Zinder regions (Sahelian zone). To collect representative samples of the main phoenicicultural zones of Niger, a survey was carried out on 60 producers in 20 representative villages (palm groves) of the two main phoenicicultural zones. The sampling method in this study consisted of quota oriented sampling. The carried out survey was to fill a questionnaire during individual farmers interview. From the interview, data like information related to producers (farmers), the cultural practices implementation (fertilization, irrigation, pruning, artificial pollination, burning technique, sowing and rejection multiplication, appropriate pruning time, underlying culture, reduction of inflorescence), knowledge on date palm diseases and solutions, quantitative and qualitative production of dates, the date palm use, the palm groves environment, other activities than phoeniciculture, social interests of the date palm, future prospects that have been identified, as well as the history of palm groves and the depth of the ground water.

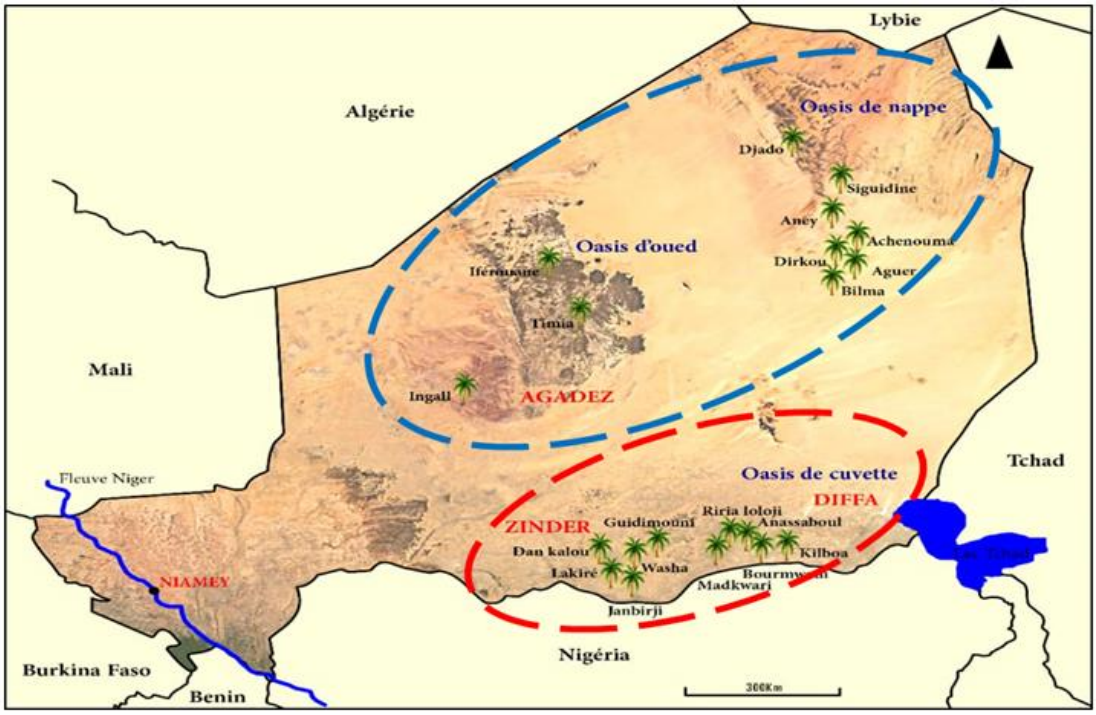

Fig. 1. Geographical location of the study area. Sahara: Strip circled in blue and Sahel: strip circled in red

2.3 Data Analysis

The relative frequencies of the responses were used to describe the level of farming practices implementation, the socio-economic status and the belonging to agro-climatic zones of palm groves. The index of socio-economic status of producers and the producer fidelity index of cultural practices implementation were computed.

- Socio-economic index determining the socio-economic information of each of the date palm producer is computed as follows:

$$I_{SE} = \frac{1}{N_{PSE}} \sum R_{positives} \quad (1)$$

- Index of fidelity to the implementation of cultural practices determining the fidelity of cultural practices implementation taken together by producer is determined by the following formula:

$$I_{PC} = \frac{1}{N_{OC}} \sum R_{positives} \quad (2)$$

With I_{SE} the socio-economic status index of growers; N_{PSE} number of socio-economic parameters considered; I_{PC} the fidelity index to the implementation of cultural practices; N_{OC} number of cultural practices considered and $R_{positives}$ number of positive responses recorded by each date palm producer.

2.4 Estimation of Phoenicicultural Potential

Survey data from the two phoenicicultural areas were used to estimate following parameters: date palm grown area, the feet number, and date palm production and income generated. The mean of feet number, the date production per producer, the 4 date palm feets area, the mean income per producer were estimated and standardized as follows:

$$\mu_i = \sum_{j=1}^{N-Nva} x_{i.} \Big/ N - nva \quad (3)$$

With μ_i the mean without extreme values of the parameter i , $x_{i.}$ The values taken by the parameter i, N the number of responses in the area and nva the number of the extreme values removed. Average productivity was multiplied by the number of productive feet to determine production per area. The mean of feet number per farm was multiplied by the number of farms to determine the number of feet per zone, the income mean per producer was multiplied by the number of producers to estimate the income/zone/year and the average grown area per 04 date palm feets was multiplied by the total number of feet divided by 04 to estimate the date palm occupied area. The yield per area was estimated as follows:

$$Yield = Total\ Production\ /Total\ area \quad (4)$$

2.5 Correlation Coefficients

Spearman's rank correlation coefficients (*Rho*) based on 100,000 permutations were estimated to mainly assess the relationships between the geographic position of palm groves, the depth of ground water and the quantitative and qualitative production of dates.

Data were computed and analysed using the caret package [18] in the R version 3.5.1 statistical environment [19].

3. RESULTS

3.1 Palm Groves and Producers Characteristics

Phoeniciculture is older in the Saharian zone (1570 years) than in the Sahelian zone (100 years) (Table 2). The ground water is moderately deeper in the Saharian zone (5 m) than in the Sahelian zone (2 m) (Table 1). Ethnic diversity is greater in the Sahara (07 ethnic groups) than in the Sahel (02 ethnic groups). In Saharian zone, Toubou is the majority ethnic group with 47% followed by Kanuri (17%) and Touareg with 17%, Ingallawa (10%) and Guesibida (03%), Kandiri (03%) and Tassawak (03%). In Sahelian zone, Kanuri with 53% and Hausa with 47%.

According to survey results from both Sahelian and Saharan populations, all date palm parts are used in Niger (Table 2). The fruits are used for food and feed and also sold for incomes; leaflets are used for making the mat, rope, chair and feeding cattle; spine used for the palisade and sold for financial incomes; stipe for the beam of houses and the sap of the male plant heart is consumed as juice (Table 2). A small difference is also noted between the zones (Sahara and Sahel) for the uses of the different parts of the date palm (Table 2).

Table 1. Age of phoeniciculture, depth of aquifer and ethnic groups by area

Zone	average age of phoeniciculture (year)	Average depth of the water table (m)	Ethnic groups	
Saharian	1570	5	**07 ethnic groups**	
			Toubou	47%
			Kanouri	17%
			Touareg	17%
			Ingallawa	10%
			Guesibida	03%
			Kandiri	03%
			Tassawak	03%
Sahelian	100	2	**02 ethnic groups**	
			Hausa	47%
			Kanuri	53%

Table 2. Uses of the different parts of the date palm by area

	Uses of date palm	
Partie	**Sahelian zone**	**Saharian zone**
Date palm fruits	Household consumption (15%), animal feed (5%), socio-cultural activities (5%), sales for financial income (75%).	Household consumption in several forms (25%), animal feed (10%), socio-cultural activities (5%), sale for financial income (60%).
Leaflets	Feeding cattle, making mats, rope, chairs, hut roofs, attics and sheds and huts.	Feeding of cattle, roofing of huts and sheds and huts, widely used for the manufacture of handicrafts (vanity, basket).
Spine	Firewood, palisade of houses and gardens, manufacture of beds, chairs, used for roofing huts, huts, and sale for financial income.	Firewood, palisade of gardens, manufacture of beds, used for roofing hangars and sale for financial income.
Stipe	Used for beams of houses and wells, as door wood for houses and gardens.	Used for beams of houses, hangars.
Heart of male plant	The meristem of the male foot is consumed and the sap of the foot is consumed in the form of juice.	The meristem of the male foot is consumed and the sap of the foot is consumed in the form of juice.

3.2 Cultural Practices Implementation Level

The level of cultural practices implementation depends on the cultural practice, the area and the grower (producer) (Fig. 2). Significant difference exists between the two phoenicicultural zones of Niger based on the frequency of different cultural practices implementation.

3.3 Date Palm Heritage, Production and Profitability Estimation

The date palm area in Niger was 4, 615.68 hectares, 42.03% is in the Sahara and 57.97% in the Sahel. The date palms plants number in Niger was 1, 125, 552, 68.95 and 31.05% were respectively Saharian and Sahelian zones. The dates production in Niger was 25, 999.224 tonnes. 64.80% of this production is from Saharian zone while 35.20% is from Sahelian zone. The income generated by the date palm in Niger was 5.15 billion CFA francs so around 9363636.36 dollars, including 80.19% from the Sahara and 19.81% from the Sahel (Table 3). The date yield in Niger was 5.63 t ha^{-1} (Table 3).

No significant influence growers age was observed on the quantitative and qualitative production of dates in Niger. However, it was observed that the ethnic group influenced the quantitative date production (0.023) but has no significant effect on qualitative production (0.362) (Table 4). Findings of this study revealed also that the main activity of the respondents

influenced the qualitative date production (0.045) (Table 4). The agro-climatic characteristics of zones influenced quantitatively (0.001) and qualitatively (0.033) the dates production. Similarly, the socio-economic index (0.005) and fidelity index of cultural practices implementation (0.035) influenced the quantitative production of dates (Table 4).

The productivity of date palms and the qualitative production of dates varied significantly according to agro-climatic zones (Fig. 3). Thus, Sahelian zone date palms were significantly more productive than Saharan zone date palms (Fig. 3a) while Saharan zone date palms produced high quality dates compared to Sahelian date palms (Fig. 3b).

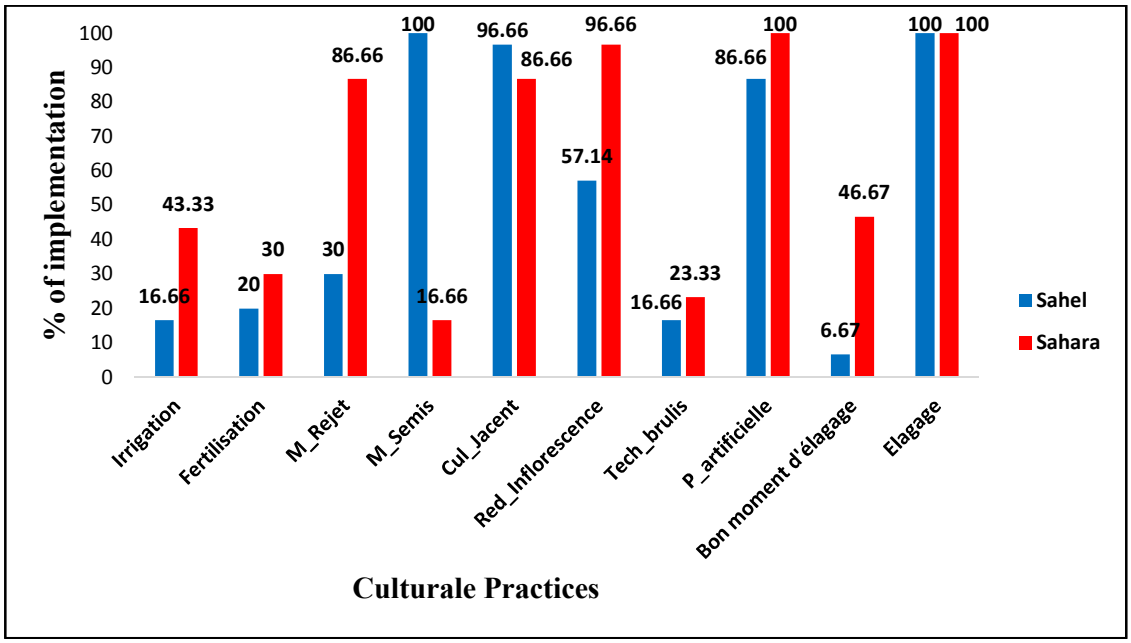

Fig. 2. Frequency of cultural practices implementation according to zones: M_Rejet = vegetative multiplication, M_Semis = multiplication by sowing, Cul_Jacent = underlying culture, Red_Inflorescence = reduction of inflorescences, Tech_brûlis = burning technic, P_artifitielle = artificial pollination

Table 3. Estimated area, number of plants, production, income and yield

Zone	Area (ha)	Number of plants	Production (Tonnes)	Income (Billion FCFA)	Yield (t/ha)
Sahara	1 940.28	776 112	16 847.224	4.13	8.68
Sahel	2 675.4	349 440	9 152.000	1.02	3.42
Niger	4 615.68	1 125 552	25 999.224	5.15	5.63

Table 4. Influence of anthropological, socio-economic and climatic parameters on profitability

Factor	Productivity (P-value)	Qualitative production (P-value)
Age	0.607 ns	0.578 ns
Ethnic group	0.023 *	0.362 ns
Principal activity	0.133 ns	0.045 *
Agro-climatic zone	0.001 **	0.033 *
Socio-economic index	0.005 **	0.063 ns
Fidelity index of cultural practices implementation	0.035 *	0.287 ns

*Code: ns = not significant, * = significant, ** = highly significant*

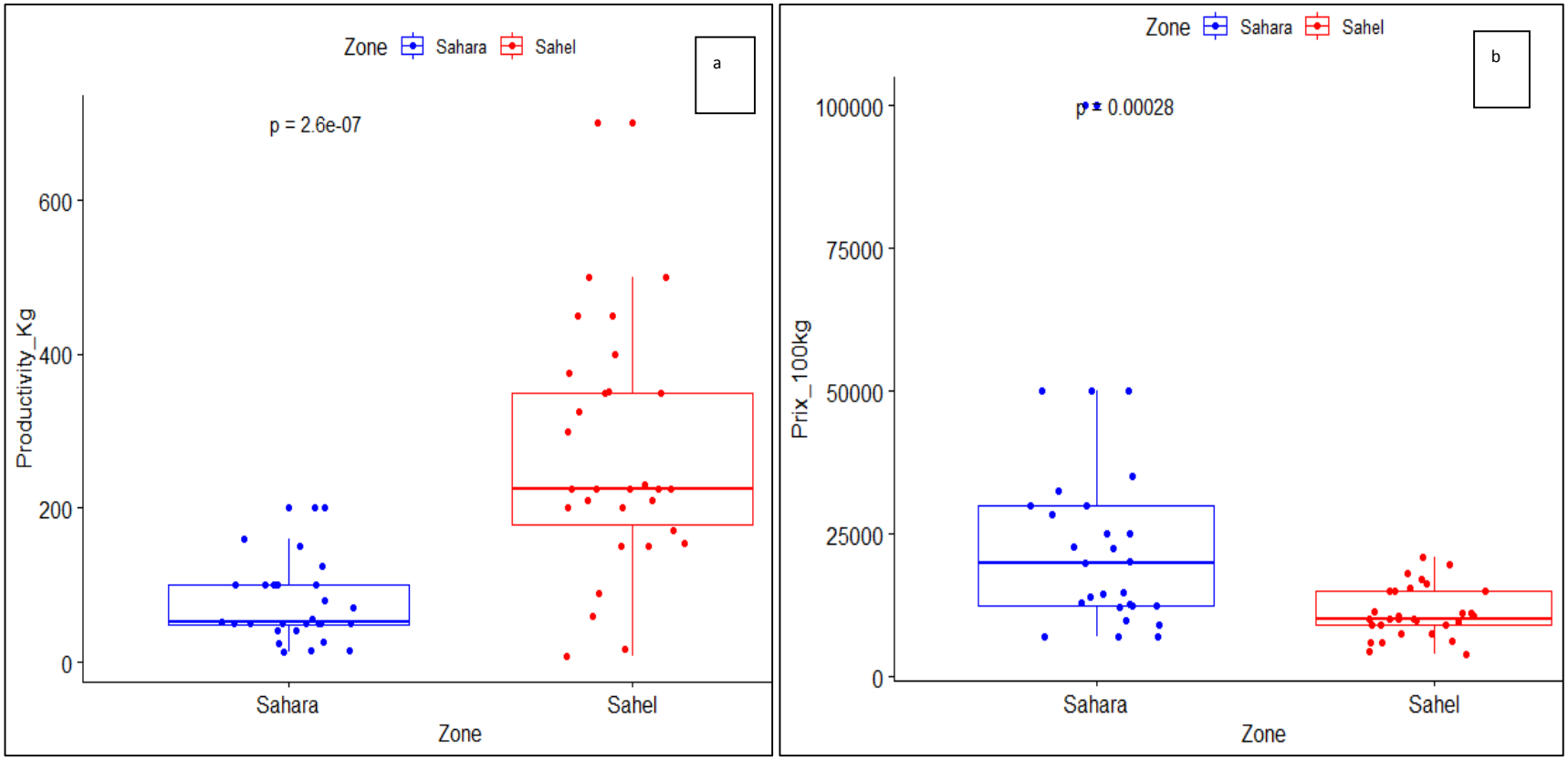

Fig. 3. Variation in date palm productivity (a) and quality of production (b) according to agro-climatic zones

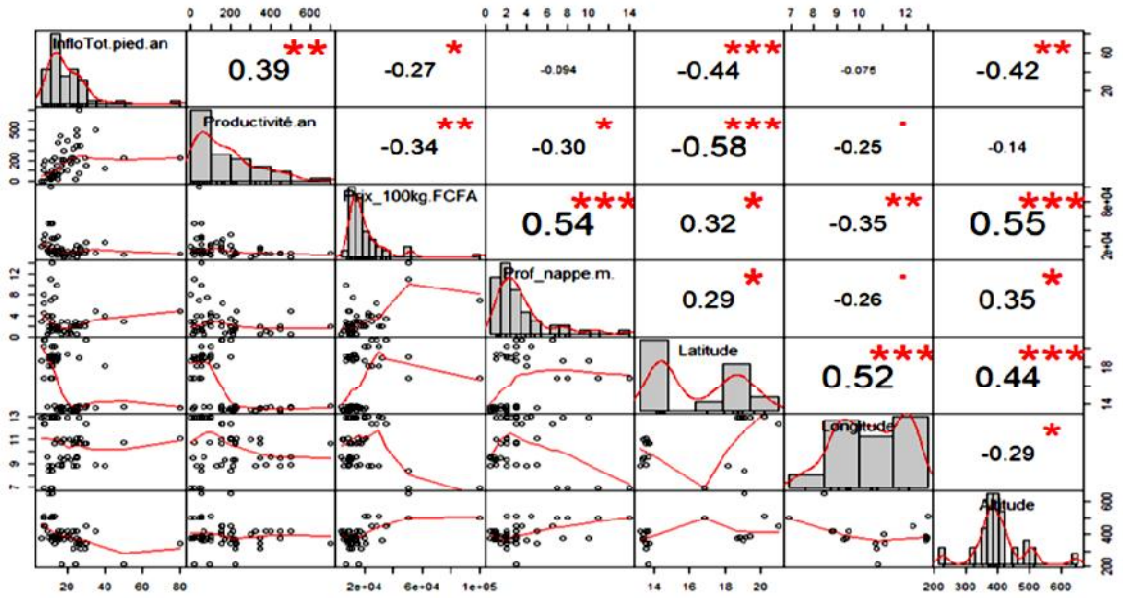

Fig. 4. Spearman rank correlation coefficients between profitability, depth of the water table and the geographical position of palm groves: Based on permutation test

*Codes: * significant, ** very significant, *** very highly significant*

3.4 Correlation between Profitability and Geographic Position of Palm Groves

The productivity of date palms is negatively correlated with latitude (-0.58) and with altitude (-0.42) (Fig. 4). The productivity of date palms changed inversely with the latitudinal and altitudinal gradients. The regime number per plant was also negatively correlated with latitude (-0.44) and altitude (-0.42). As for the dates quality, it was positively correlated with the latitude (0.32) and the altitude (0.55). Indeed, the best date quality (high price of 100 kg) was observed in the highest altitude and latitude (Fig. 4). The depth of the ground water was positively correlated to qualitative dates production (0.54) and negatively correlated to the productivity of date palms (-0.30) (Fig. 4).

4. DISCUSSION

Previous studies [1] reported that populations of Saharian and Sahelian phoenicicultural areas of Niger are using the different parts of date palm. Phoeniciculture is a considerable source of income for populations of the phoenicicultural zones in Niger. The cultural practices, key step for quantitative and qualitative date production, are little and inefficiently practiced by Nigerien date palm producers. According to the sondage, the cultural practices implementation of phoeniciculture depends on the producer, the cultural practice and the phoenicicultural area. Fertilization is implemented by 20% and 30% of date palm producers in Sahelian and Saharian zones respectively. It therefore remains very little used in these areas with generally poor soil, while fertilization is an operation that could improve the productivity of the date palm. The standards recommended in terms of fertilization by the Technical Institute for the Development of Saharian Agriculture (ITDAS) is to amend each date palm with at least 100 kg of manure/year or 3 kg/palm tree/year of mineral fertilizer [20,13]. The poor implementation of fertilization is due to the lack of organic and chemical fertilizers in these areas. This situation could handicap the profitability of the date palm. In addition, date palm diseases unknown by 50% of date palm producers in these areas could be additional factors reducing date palm productivity and profitability. According to [21], the lack of health status control of date palm trees grown in this area could be the major factor leading to the high profitability decrease of date palm in Niger.

Pruning is the practice used by all date palm producers in these areas and this attests that they know the advantage of this practice for the profitability. However, 26.67% of date palm producer don't respect some of ecological requirements of the species (*Phoenix dactylifera*

L.) and are not well practicing the pruning technic like the appropriate date of implementation. In addition, date palm producers were not following the recommended standards like for each date tree to leave 10 palms during harvest [22]. Artificial pollination of date palms is very important and is needed for high profitability. This practice is used by 93.33% of date palm producers in these areas who know very well the appropriate moment of it implementation (afternoon towards sunset). Our findings showed that the remaining farmers (6.67%) don't need to implement the manual pollination and this lead to high production decrease due to poor fructification. Date palm tree can produce around twenty inflorescences followed by low harvest and a probable death of the date palm tree. Thus, reducing the inflorescence number is an important strategy to increase the production quality. 57.14% of Sahelian zone producers and 96.66% of Saharian zone use often this technic.

The date palm need irrigation which doesn't happen often as only 16.66% and 43.33% of date palm producers respectively from sahelian zone and Saharian zone are irrigating their palm trees. Producers also don't follow the standard recommended for irrigating a palm grove which is at least 70 liters/second/ha [13]. The consequence is water deficit leading to yield decrease (quantity and quality) and death of significant number of date palm trees.

In Niger, date palm area, which increased considerably from 1996 to 2018, is up to 4.615.68 hectares, 42.03% in Sahara and 57.97% in Sahel. In this country, date palm area was 2,800 hectares in 2016, there were around 1,125, 555 date palm trees with respectively 68.95 and 31.05% in Saharian and Sahelian zones in 2018 [23], while the date palm trees number 720,000 in 1996 [24]. The estimation of dates production in Niger was 18,000 tonnes in 2016 and 25,999.224 tonnes in 2018, 64.80% in Sahara and 35.20% in Sahel [24]. The estimated economical income generated by the date palm in Niger was 5.15 billion CFA francs (9.3 Millions USD), 80.19% from Saharian zone and 19.81% from Sahelian zone. Although the date palm is more productive in the Sahel, the profitability is higher in the Sahara. This difference could be due to the quality of dates produced in Saharian zone. The yield of date in Niger is very low compared to world yield and the poor cultural practice implementation by producers could explain this difference [23].

The rank Spearman coefficients confirmed the quantitative and qualitative difference of dates production between the two zones and showed that productivity was lower at high altitude where the quality of dates was better. The benefits from date palm depends on the geographical position (longitude, latitude and altitude) of the palm groves and the ground water [1]. The difference of profit between Saharian and Sahelian zones is mostly due to knowledge on cultural practice by producers from Sahara compared to Sahel, as Niger Saharian zone was known as traditional zone of [15]. In addition, the dry climatic

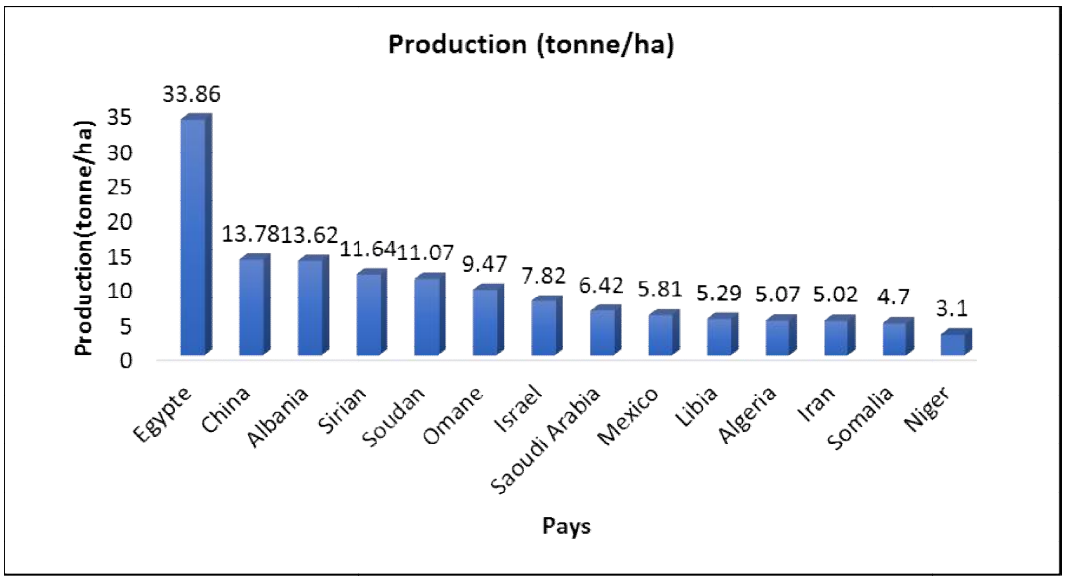

Fig. 5. Yield comparaison in tonne/hectare of Niger with others world countries [23]

conditions of dates maturity in the Saharian zone are better than in the Sahelian zone [14]. The impact of the climate (rainfall and relative humidity) on date palms productivity indicates that in the Sahelian zone date palms are more productive and has double flowering time, one during the dry season (low production but of good quality) and another (large production but of lower quality) in the rainy season with rains often happened at maturity dates [14]. The ground water depth is lower in the Sahelian zone (02 m) than in the Saharian zone (05 m) Ground water depth in Sahel led to high productivity while it led to high quality of dates in Saharan zone. The date palm profitability varies from ethnical group to another, so it means that this activity is differently considered by ethnical group. The date production is influenced by socio-economic level of farmers. Then, the date palm profitability varies according to the financial capacity of farmers, there main activities and holding technical materials.

5. CONCLUSION

The fidelity of date palm farmers to the implementation of cultural practices and the socio-economic status of farmers influence the production of dates, hence the importance of looking at the level of implementation of these practices, as well as the way they are implemented. The analysis of the different practices that are part of the date palm cultivation in Niger has shown that the implementation of these practices varies from one phoenicicultural area to another, from a palm grove to another, from a farmer to another and from one operation to another depending on the need, the specificity, the importance of these practices and the socio-economic level of the farmers. In general, there is any cultural practice that is correctly implemented by all farmers in Niger. Indeed, for a good phoeniciculture, the optimal technical way includes the following practices: Irrigation, artificial pollination, mineral and/or organic fertilization, technics of multiplication, pruning, chiselling, and reduction of inflorescences, phytosanitary treatment, plowing and development of palm groves as well as the bagging of inflorescences against pests. Some of these practices, although their economic importance, are not implemented or very insufficiently practiced and sometimes without mastery of the techniques and appropriate moments of their application (protection of the inflorescences, reduction of inflorescences, pruning and treatment plant Health). The handicap in technical materials and financial resources, the absence or the insufficiency knowledge concerning the practices related to phoeniciculture, are perceived as the main problems hindering the development of phoeniciculture in Niger. This explains important part of the instability of date palm profitability. The climatic and environmental conditions (depth of the water tables and geographical position of palm groves) also have a significant influence on the quantitative and qualitative production of dates.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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