Original Research Article

Edaphic aptness of subarid soils to lettuce (*Lactuca sativa* L.) production in social dynamics context of Diffa, NIGER

ABSTRACT

In the eastern Niger, vegetable crops such as lettuce are cultivated along the Komadougou Yobé river and near Lake Chad. Insecurity linked to terrorist groups prevents the exploitation of these areas and leads population to explore other lands. This study aims to find out whether sub-arid soils have in some places potentialities that can allow lettuce cultivation. A pedological survey was first carried out in the study area and some physicochemical soil parameters were analyzed. Then, a randomized experimental design with three cultivars ("Blonde de Paris", "Iceberg Tahoma", and "Iceberg edem") and three replicates was carried out on soils which present favorable conditions for vegetable crops. The lettuce fresh mass was determined at harvest. The results show a significant influence of the geomorphological gradient on texture classes, nitrogen contents, pH values, cation exchange capacity and level of exchangeable bases. The lowland soils are more apt for vegetable crops like lettuce. The mean of lettuce fresh mass obtained for the three cultivars is 4.8±0.5 kg.m^{-2}. Iceberg Eden records the highest values and seems well adapted to eastern Niger.

Keywords: Semi-arid sandy soil suitability; lettuce production; Eastern Niger

1. INTRODUCTION

In areas close to Lake Chad, many people are currently displaced by climate and conflict and suffer from food insecurity [1]. Climate change and insecurity linked to armed groups have disrupted people's livelihoods [2,3]. This situation has led to social dynamics in recent years in Diffa's region of Niger. The impoverishment of indigenous and refugee populations is one of the major consequences of this problem. Indeed, population movements have increased their vulnerability and exacerbated the food insecurity situation. Livelihood's development is essential and must be a priorityto promote the resilience of crisis-affected communities, reduce reliance on humanitarian aid, and ultimately promote lasting peace [4].

In the Diffa region, agriculture is one of the main household activities. Vegetable crops occupy an important place. Several nutrients like vitamin C, potassium, sodium, calcium, and magnesium are found in the leaves [5, 6]. The main vegetable crops cultivated in the region are lettuce, cabbage, tomato, onion, squash, and carrot. Lettuce is one of the most important crops because it contributes to household food security. The production is estimated at 4211 tonnes in the region. Several researchers have found marketable yields of lettuce of the order of 2.17 kg m^{-2} into semi-arid climate [6].

Otherwise, the soils that support its vegetable crops in the region of Diffa are vertisols, hydromorphic and halomorphic soils. These soils are located near the Komadougou Yobé river and Lake Chad where insecurity is more acute. The inaccessibility to these fertile lands due to insecurity leads to a disruption of the population's livelihood and the covetousness of less fertile lands. However, lettuce production is highly dependent on the soil physicochemical characteristics if the constraints linked to irrigation are removed. In fact, lettuce is grown on the loam, clay-loam, and clay soils [7]. However, soils which contain these characteristics are potentially suitable for this culture. This study aims to find out whether sub-arid soils have in some places potentialities that can allow lettuce cultivation. The objectives are to (i) identify the physicochemical potentialities of subarid soils, (ii) to assess their aptness for lettuce production and (iii) to evaluate the influence of cultivars on the lettuce yield.

2. MATERIAL AND METHODS

2.1 STUDY AREA

The study was carried out during the 2019 rainy season in the Diffa region in eastern Niger. The site is located between 13°38' and 13°40' North latitude and 12°30' and 12°33' East longitude. The climate is arid with two seasons, a dry season from October to May and the rainy season from June to September [8]. The average rainfall for the last 30 years is 308.1±93 mm with maximum temperatures up to 36.84°C. The geomorphology is dominated by dune flats and lowlands area. The soil is subarid with sandy texture on the dune and clayey-sandy in the depressions. The vegetation is steppe type characterized by *Acacia tortilis* and *Balanites aegyptiaca* and grazing is the main form of exploitation of theses pastoral resources [9].

2.2 SOIL PROSPECTION AND LAB ANALYSIS

Soil pits were opened according to the geomorphological units. The soil profiles were described, and soil samples were taken depending on the horizons. The samples were analyzed at the International Crops Research Institute for the Semiarid Tropics (ICRISAT) laboratory of Niger. The granulometry was carried out according to the Robinson pipette method, making it possible to separate and measure five granulometric fractions: clays (<2µm), fine silts (2-20 µm), coarse silts (20-50 µm), fine sands (50-200 µm) and coarse sands (200-2000 µm). The silts and sands classes were obtained by summing the corresponding sub-classes. pH was measured in a soil to water ratio of 1:2 by pH Meter. Organic carbon was determined by using the Walkley and Black [10] method. Organic matter (OM) was deduced by multiplying by 1.724. Total Nitrogen (N) was determined through Kjeldahl method [11], available phosphorus by Bray I method [12]. Cation exchange capacity (CEC) and exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) through ammonium acetate method to pH=7 [13].

2.3 EXPERIMENTAL DESIGN AND DATA COLLECT

The experiment was carried out into clayey-sandy soils located in lowland. A random block design was using to test three cultivars (Blonde de Paris, Iceberg Tahoma, and Iceberg edem) replicated three times. Therefore, nine plots were arranged in the experiment design. The plot cover 20 m² (10 m × 2 m), separated by 2 m into blocks and 3 m between blocks. In each plot, one cultivar was transplanted with a density of 12 plants/m² after two weeks of seed germination. 200g/m² of organic manure and 150g/m² of mineral fertilizer (NPK, 15-15-15) were provided in all plots. Irrigation is done in all the plots according to the crop's water needs. The lettuce fresh mass was determined at harvest.

2.4 STATISTICAL ANALYSIS

Principal component analysis (PCA) was performed on a matrix of 30 observations (soil samples) and 12 physicochemical parameters. The variables contributions along the main dimensions were used to characterize soils types. A color palette was used to highlight the variables contribution and the confidence ellipses was shown by soil type. Moreover, to compare soil physicochemical parameters between the soil types, a one-way analysis of variance was performed. In case of non-normality and heteroscedasticity, the nonparametric Mann-Whitney test was applied. The mean of the fresh mass was also compared between three cultivars using Kruskal-Wallis test. The R software version 3.6 [14] was used for all analyses.

3. RESULTS AND DISCUSSION

3.1 Relationship between soil type and geomorphology

PCA performed on physicochemical data matrix shows that the first two components explained 62.8% of total variance with 45.2% for first component and 17.6 % for second component (Fig. 1). Cation exchange capacity, silt, clay, and exchangeable bases are most contribute to the positive pole of the principal component 1 (PC1), while sand and pH to the negative pole. Principal component 2 (PC2) is mainly defined by organic matter and nitrogen to the positive pole. These results link first component to a geomorphology gradient and second component to depth gradient. Thus, analysis of both gradients highlights two soil type. Soils A in the positive pole of PC1 and located into lowlands under a steppe vegetation of *Accacia tortilis* or and *Boscia senegalensis*. Species like *Chloris pirieuri*, *Alysicarpus ovalifolius, Dactyloctenium aegyptium, Digitaria horizontalis, Zornia glochidiata, Spermacoceae radiata, Acacia tortilis, Boscia senegalensis and Balanites aegyptiaca* are flora characteristic of these zones. They have a fine texture, better retention capacity and good availability of bases on the whole profile. The topsoils are more content of organic matter and nitrogen. On the negative pole of PC1, soils B is located on the dunes under steppe vegetation characterized by species such as *Acacia tortilis, Boscia senegalensis, Tribulus terrestris, Zornia glochidiata* and *Cenchrus biflorus*. These soils have sandy texture with a low water retention capacity and exchangeable bases. It appears that the geomorphological gradient is the factor determining the physicochemical characteristics of the soils in the study area [15,16].

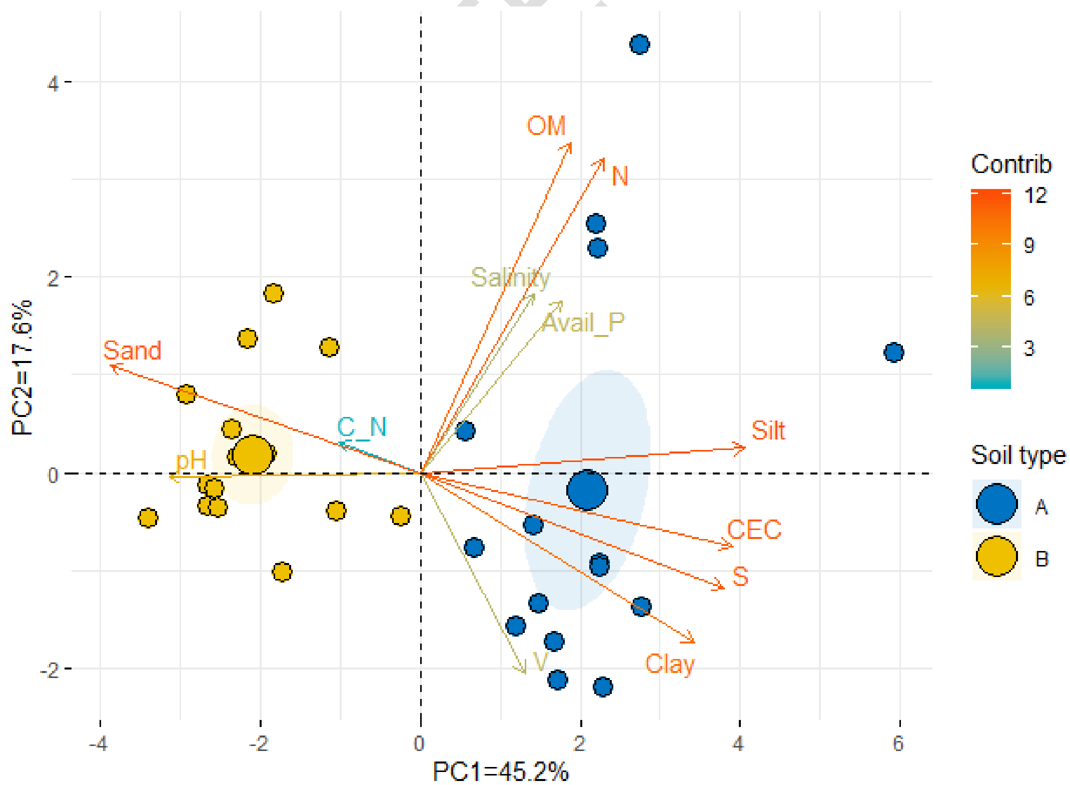

Figure 1 : Factorial design of the principal component analysis

S : sum of the exchangeable bases ; V : Bases saturation rate ; C_N : carbon to nitrogen ratio Avail_P : Assimilable phosphorus; contrib: contribution

3.2 Soils physicochemical characteristics

A significant influence of geomorphology gradient was found for texture classes, Nitrogen contents, pH values, cation exchange capacity, and the levels of exchangeable bases (Table 1). The means comparison of these soils parameters shows significantly higher values for lowland soils. Table 1 shows significantly higher clay (25.24±8.6%) and silt (11.36±3%) values and lower sand values (63.39±10%) for lowlands soils than dune soils. It emerges that the texture is clayey-sandy for lowlands soils and sandy for dune soils. The organic matter (0.336±0.2%) and nitrogen (0.016±0.01%) contents in the depression soils are 2 times higher than those obtained into dune soils (0.18±0.1%; 0.007±0.01% respectively) with a significant difference for Nitrogen. These properties could be linked to the redistribution of organic carbon on the soil surface and the relationship between organic matter and nitrogen in sub-arid soils. Indeed, besides the vegetation of lowland which provides a large part of the organic matter compare to dune vegetation, the lowland also constitutes a convergence area of organic fragments which come from the summit parts through wind erosion. Indeed, soil properties generally reflect topography and set a pattern for plant productivity and soil carbon accumulation [17]. Yoo *et al.,* [18] reported that the spatial distribution of organic carbon over the earth reflects the combined effects of geomorphological processes and the biological carbon cycle. Lowland soils offer higher values for the sum of the exchangeable bases and cation exchange capacity (CEC) 6,78±0.6 $cmol^+.kg^{-1}$; 8.27±0.3 $cmol^+.kg^{-1}$) than dune soils. pH values are significantly influenced by soil type, its slightly more alkaline for dune soils (7.7±0.5) as opposed to lowland soils (6.9±0.4). In fact, in soils with a low organic matter content, clay plays the main role in the structuring of the soil. Kavdir *et al.* [19] reported that the soil tensile strength, considered to be one of the most useful indicators of the soil structural condition, was mostly influenced by clay content. The results also highlight the potential of clays to retain and exchange cations through CEC values. The exchange complex is more provided with divalent Ca^{2+} and Mg^{2+}cations for lowland soils than dune soils. For both soils, Ca^{2+} is more abundant among the bases while sodium is a minority. In fact, calcium and magnesium play a very important role in clay flocculation and improve the stability of soil aggregates [20]. The analysis of these physicochemical characteristics of the soil shows that lowland soils are moresuitable for vegetable crops like lettuce.

Table 1 : Mean (m) and standard deviation (σ) of soil physicochemical parameters for two soil types (A and B)

Physicochemical parameters	Lowland soils (Soil A)		Dune Soils (Soil B)		*P*value
	m	σ	m	σ	
Sand (%)	63.39 (b)	10.3	83.87 (a)	2.6	0.00
Silt (%)	11.36 (a)	3.0	3.22 (b)	1.8	0.00
Clay (%)	25.24 (a)	8.6	12.90 (b)	1.5	0.00
OM (%)	0.336 (a)	0.2	0.18 (b)	0.1	0.06
N (%)	0.016 (a)	0.01	0.007 (b)	0.01	0.03
$C.N^{-1}$	12 (a)	3	14 (a)	4	0.23
pH	6.9 (b)	0.4	7.7 (a)	0.5	0.00
Avail P ($mg.g^{-1}$)	9.945 (a)	16.5	7.55 (a)	3.1	0.16
CEC ($cmol^+.kg^{-1}$)	8.27 (a)	0.3	4.46 (b)	1.3	0.00
S ($cmol^+.kg^{-1}$)	6.78 (a)	0.6	3.44 (b)	1.1	0.00

Ca^{2+} ($cmol^{+}.kg^{-1}$)	4.66 (a)	0.6	2.46 (b)	0.9	0.00
Mg^{2+} ($cmol^{+}.kg^{-1}$)	1.62 (a)	0.4	0.62 (b)	0.2	0.00
K^{+} ($cmol^{+}.kg^{-1}$)	0.47 (a)	0.1	0.33 (b)	0.1	0.05
Na^{+} ($cmol^{+}.kg^{-1}$)	0.08 (a)	0.04	0.04 (b)	0.01	0.00
V (%)	81.9 (a)	6.4	77.1 (a)	6.9	0.06

Within the same line the values with different letters are significantly different (Fisher or Kruskal-Wallis test) at probability level of 0.05.

S : sum of the exchangeable bases ; V : Bases saturation rate ; C_N : carbon to nitrogen ratio; Avail_P : Assimilable phosphorus; OM: Organic matter; N: Nitrogen; CEC :cation exchange capacity

3.3 Lettuce fresh mass

The mean fresh mass of lettuce obtained for the three cultivars are 4.8±0.5 $kg.m^{-2}$. However, yield is significantly influenced by cultivar type (***P*** =.003). These results may be related to irrigation water supply and fertilization. For this experiment conducted in the rainy season, the irrigation was done according to the lettuce water requirements and soil clayey-sandy texture can further water retention into the soil. Kuslu *et al.* [21] reported that the increase of lettuce production is significantly linked to the quantity of irrigation water. For other authors, the increase of clay content leads to reduction in the water-repellent effect of the soil [22, 23]. In addition, the result showed that the organic matter content is 0.336±0.2%. This organic matter linked with clay, allows a good structuring of the soil and foster a better development of the root system. Indeed, the nutrient uptake by crop plants is strongly influenced by root morphology and soil properties [24, 25, 26]. Regarding fertilization, the low content of organic matter and nitrogen may justify the amounts of organic manure and NPK supplied. The productivity of a vegetable crops depends on the quality and quantity of fertilizer used [27, 28, 29]. In fact, nitrogen is one of the most important nutrients that promote vegetative growth of plants [30, 31]. It's probably for these reasons that the yield obtained is higher than that obtained by some authors (2.17 kg m^{-2}) in semi-arid zone [6].

The Iceberg Eden (V3) cultivar have the highest values of lettuce fresh mass (5.25±0.1 $kg.m^{-2}$). The other two cultivars (Blonde de Paris, V1; Iceberg Tahoma, V2) are also significantly different (***P*** = .0079) and the lowest values are recorded by Blonde de Paris (4.22±0.4 $kg.m^{-2}$). The lettuce yield is also linked to cultivars and Iceberg Eden appears to be well adapted in the east of Niger. This peculiarity may be due to the genetic factors of this cultivar. Some authors reported that Iceberg Eden produced larger leaves which may have improved rate of photosynthate production and massive root growth to enhance nutrient uptake [32]. It therefore represents the cultivar which adapts to climatic and soil conditions with yields acceptable in the study area.

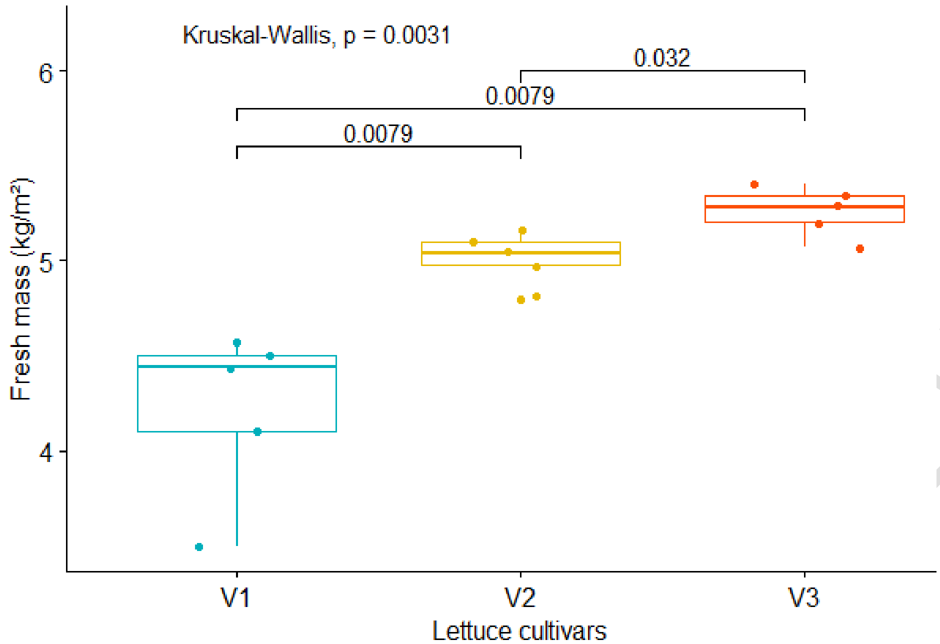

Figure 2: Comparison of mean fresh mass of lettuce cultivars.
V1: Blonde de Paris; V2: IcebergTahoma; V3: Iceberg Eden

4. CONCLUSION

This study is carried out to assess the suitability of sub-arid soils for lettuce production in an insecurity context into Diffa Region. It appears that the characteristics of the subarid soils in the Diffa region are influenced by geomorphology and the lowland soils are suitable for vegetable crops. They have fine texture, with a good capacity and availability to retain exchangeable bases and a high potential of nitrogen compared to dune soils. These soils can produce significant amounts of lettuce for local populations. It's constitutes an important contribution to food nutrition and thus improves the livelihoods of populations in this insecurity context.

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