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The Influence of the Invasive Plant *Taraxacum officinale* (FH Wigg) on Soil Characteristics

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The study which was aimed at detecting the effects of the properties of *Taraxacum officinale* on the characteristics of the soils was carried out in a garden in Use Offot Community in Uyo, Akwa Ibom state using the purposive sampling method. The samples were collected at a depth of 0-30 cm from different points in the study area, and were bulked into one composite sample. Standard procedures were adopted in the analyses of the soil sample and the results of the analysis of the sample showed that the soil with *Taraxacum officinale* had a neutral soil pH (7.055) as against the control soil which had a slightly acidic pH (6.72). The organic carbon, total nitrogen and available phosphorus contents were 0.78 %, 0.04 %, and 87.04 mg/kg respectively. The average cation exchange capacity (3.25 cmol/kg) was low; also the soil texture of the samples were identified as loamy sand. These values revealed that *Taraxacum officinale* had effects on the physicochemical properties of the soil it grew on.

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1. INTRODUCTION

Invasive plants have a multitude of impacts on plant communities through their direct and indirect effects on soil chemistry and ecosystem function [1]. These plants modify the soil environment through exudates that affect soil structure and mobilize and/or chelate nutrients [2]. Plants can affect soil structure (particle aggregation) by creating pores in soil; and plant growth promotes rapid wetting and drying cycles that cause shrinkage and strengthening of the soil [3]. Some invasive species may gain a competitive advantage through the release of compounds or combination of compounds that are unique to the invaded community [2]. Studies based on meta-analysis indicates that plant invasions generally increase nutrient pools and also enhance the rate of soil processes such as litter decomposition and mineralization, possibly accelerating nutrient cycling. This is because invasive species have significantly higher, in comparison to non-invasive ones, values of performance-related traits such as physiology, leaf-area allocation, shoot allocation, growth rate, size and fitness, which are driving factors in regulating carbon and nitrogen cycles [4].

Changes in the soil properties brought about by plant invasion are problematic as they may lead to positive feedbacks that stabilize or accelerate invasion. The changes may persist after the removal of an invasive plant and limit recolonization by native plant communities. This phenomenon known as invasive plant legacy, has implications for restoration of invaded site [5].

Taraxacum officinale is among the most frequent and aggressive invasive alien plants found in natural, extensively managed and man-made habitats [6]. It is considered a transformer that change the character, condition, form or nature of ecosystems over a substantial area'due to, for example, excessive or limited use of resources, promotion of erosion or stabilization of soil, or accumulation of litter. However, some data indicates that the influence of invasion on ecosystems may considerably vary among transformer invasive species [7].

T. officinale is considered one of the most difficult weeds to control because its seeds are spread quickly and easily by wind. *T. officinale* has shown high tolerance to abiotic stress and efficient use of resources due to high plasticity in morphological and physiological traits [8]. Thus, when it experiences favourable abiotic conditions *T. officinale* shows enhanced abundance, physiological performance, biomass accumulation, survival and seed production [8,9]. It was found that on French sub-Antarctic islands, where *T. officinale* was introduced, the disappearance of native plants over wide areas, due to the impact of rabbits and global warming, coincided with a demographic explosion of *T. officinale* and other introduced plants, thus resulting in the homogenization of plant communities [10].

T. officinale is a perennial plant in the sunflower family - Asteraceae. It is distributed in almost every temperate and subtropical region of the world and is typically found in the temperate climate and it grows in loose soil and open spaces [11]. The roots of this plant are cylindrical, thick and possess vertical rhizomes that form a tap root which exudes a milky juice when cut. In the upper part of the rhizome, there are semicircular scars caused by the insertions of the leaves of the previous years. Its cotyledons are pale, dull, yellowish-green, oval, and have smooth edges. Its young leaves form a basal rosette and are oval to oblong with long hollow leaf stalks (petioles). The stems are erect, about 2 to 12 inches tall, hollow, leafless, filled with milky juice, and terminate in a single flower head. The leaves of the plants are basal, bright green, thin, hairless, between 3 to 10 inches long, and jagged around the edges with lobes or teeth of various sizes and shapes. The terminal lobe is usually the largest and lobes become smaller and more deeply divided toward the leaf base. The leaf base tapers into a hollow, short petiole; and mature leaves exude a milky juice when cut or broken. *T. officinale* has bright yellow, 1- 2-inch-wide flowers form at the tips of long, hollow, flower stalks. Flowers mature into fluffy white seed heads. The single-seeded fruits are brownish, narrow, about $^{3}/_{16}$ inch long, and tapering to a slender beak that is 2 to 3 times as long as the seed. At the top of the beak are soft, white, bristly hairs called pappus [11]. Although *T. officinale* is considered a weed, it has some economic benefits which include its uses in the production of food and medicines [12,13].

Studies have shown that there are different characteristics which may be responsible for the spartial or temporal variation in soil physico-chemical properties. Some may be as a result of

land use, tillage practices and littoral origin of the soil [14]. Soil properties influence vegetation, and vice versa. Selective absorption of nutrients by different plant species and their capacity to return these nutrients to the soil, brings about the changes in the biochemical properties of the soil, as well as that of the plants [15]. This research seeks to detect if the properties of *Taraxacum officinale*, have an effect on the characteristics of the soils in which they are found.

Fig. 1. *Taraxacum officinale* in its natural habitat

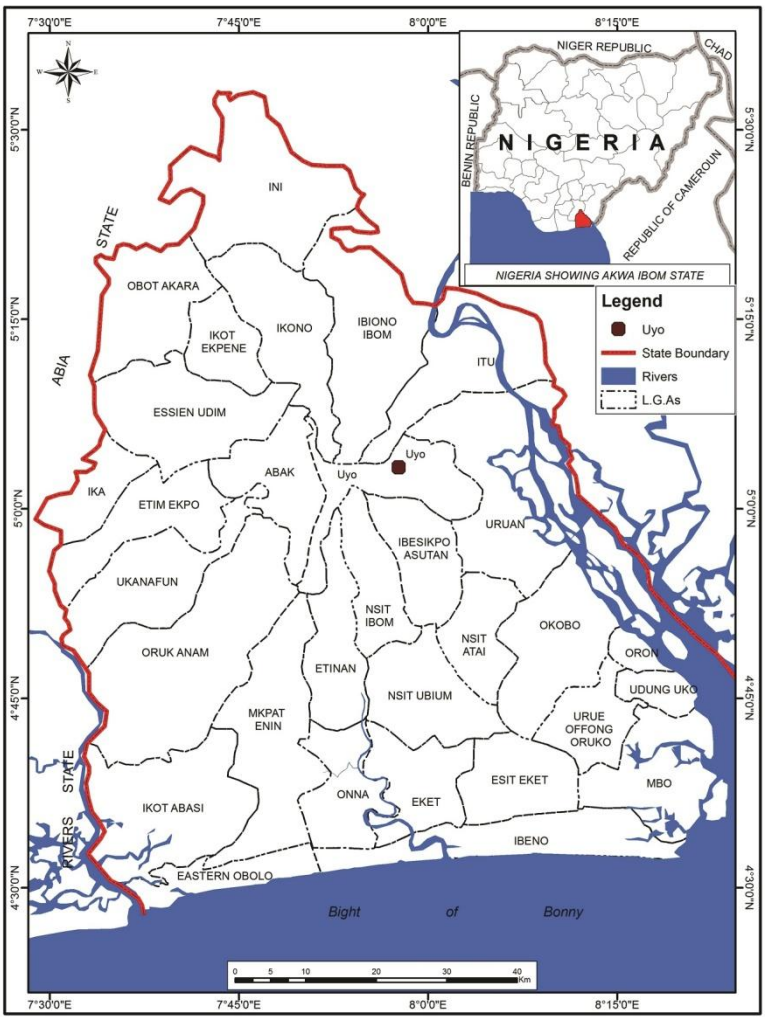

Fig. 2. Map of Akwa Ibom State indicating the city in which study location is found

2. MATERIALS AND METHODS

2.1 Description of Study Area

The study was conducted in a garden at Use Offot, in Uyo, Akwa Ibom State which lies within the latitude $5^{o}02^{¨}$N and longitude $7^{o}97^{¨}$E in the south-south region of Nigeria. The area has an average temperature of about 24.8^{o} C and an annual rainfall of about 34.3mm. Uyo is geographically bound to the east by Uruan Local Government Area, to the west by Abak Local Government Area, Ibiono Ibom Local Government Area to the North and Ibesipko Asutan Local Government Area to the South [16].

2.2 Soil Sample Collection

The samples were collected in July, 2021 at the study area, using a soil auger at the garden, by burrowing into the soil at the depth of 0-30 cm at different locations within the study area. The locations were chosen through the purposive sampling method, in the area which the *Taraxacum officinale* was dominant, while the control sample was collected as control from an area 100m away from area with *Taraxacum officinale* which lacked the invasive species. The collected samples were stored in transparent Ziploc bags and were taken to the University of Uyo, Soil science department for analyses.

2.3 Laboratory procedure for Soil Analysis

The collected samples were spread to dry for about 24 hours because the samples collected were very moist. After air drying, different tests were carried out to aid the analyses following the standard procedures outlined by the Association of Official Analytical Chemist (AOAC) [17].

2.4 Particle Size Analysis

This analysis was done to determine the particle size composition of the soil. It was done using a hydrometer.

Apparatus

- Mechanical Stirrer
- glass cylinders
- Thermometer
- Hydrometer

Method

50 g of each soil sample was put in a stirrer cup, and 20 ml of Calgons reagent (Sodium hexametaphosphate) was added as a dispersing agent. Water was added, and each mixture was stirred with the mechanical stirrer 5 minutes. After stirring, the mixture was added into a 1000 ml cylinder, and the solution was brought to mark by adding water. The solution was shaken vigorously by inverting the cylinder multiple times.

After shaking about three time, the cylinder was brought to rest. After about 40 seconds, the hydrometer was placed in the solutions and each reading was taken.

After the readings of the hydrometer were taken, a thermometer was used to measure the temperature of the solution. The suspension was allowed to stand for at 2 hours, after which the second readings of the hydrometer and the thermometer were taken. The first reading taken was the measurement for the percentage of silt and clay in the solution, while the second reading taken was the measurement of the total clay in the suspension. The results were corrected to a temperature of 20°C. The standard hydrometer calibration was given as 0.3 and for every temperature increase above 20°C, the hydrometer reading were corrected with the formula.

The percentage sand, silt and clay were calculated as:

$$\% \text{ sand} = 100 - 2[H_1 + 0.3(T_1 - 20)]$$
$$\% \text{ clay} = 2[H_2 + 0.3\,(T_2 - 20)]$$
$$\% \text{ silt} = 100 - (\% \text{ sand} + \% \text{ clay})$$

Where

H_1 = first hydrometer reading after 40 seconds
T_1 = first temperature reading after 40 seconds
H_2 = second hydrometer reading after 2 hours
T_2 = second temperature reading after 2 hours
0.3 (T 20) = the temperature correction to be added to the hydrometer reading where T = degree Celsius.

The textural classification of the samples were obtained using the USDA Textural Triangle with the particle size analysis result.

2.5 Determination of Soil pH and Conductivity

This is use to determine the pH and electrical conductivity of the soil. It was done in the ratio of 1:2 soil to solution.

Apparatus

- Glass electrode pH meter (pHS-25 search tech instruments)
- Labtech dig conductivity meter
- 50 ml beakers
- Stirring rods

Method

10 g of each soil sample was weighed out and mixed with 20 ml of distilled water in 50 ml beakers. The mixture was stirred slightly and allowed to settle for about 30 minutes. Using the electrode of the pH meter, the pH of the soil samples were determined and recorded. After each measurement, the electrode was rinsed with distilled water and dried after each measurement. After testing for pH, the samples were tested for conductivity, using a conductivity meter, and the results were recorded.

2.6 Determination of available phosphorus using Bray 1 Method

This is used to determine the available phosphorus within that soil.

Apparatus

- Mechanical Shaker
- 20 ml test tubes
- Centrifuge
- Photo electric colorimeter.

Method

10 g of each soil sample was weighed and 20 ml of Bray 1 solution was added to the weighed sample. The mixture was shaken for a minute in a mechanical shaker, then added into a centrifuge to separate. The solution was removed from the centrifuge and the colour observed was pale yellow. On removal, 8 ml of Reagent B was added to the solutions to develop the colour to blue. After the solutions had developed colour, 27 ml of distilled water was added to each solution to bring to 50 ml. The solution was allowed some time to develop, then the readings were taken with the use of a photoelectric colorimeter.

$$\frac{\text{Volume of solution}}{\text{weight of soil}} \text{ x Final volume x Absorbenc}$$

2.7 Determination of Total Nitrogen

5 g of soil was weighed out and transferred to 500 ml Kjeldahl flask. About 11 g of digestion mixture was added to the flask. 25 ml of concentrated H_2SO_4 was added and swirled gently until the content was thoroughly mixed. The flask was placed on Kjeldahl digestion apparatus and heated at low heat for four (4) hours until frothing ceased or organic matter destroyed as evidenced by the light grey colour. It was further heated for 30 minutes. The heat was turned off, flask removed, capped immediately with beaker and left to cool. During the cooling process, 25 ml of 4% boric acid (plus indicator) and 25 ml distilled water were placed in 500 ml Erlenmeyer flask. The flask was placed under the condenser of the distillation apparatus such that the end of the tube was below the level of H_3BO_3. The cooling water in the condenser was turned on and allowed to run. After cooling, 250 ml of distilled water was added the Kjeldahl flask and the contents mixed thoroughly. The flask was tilted to an angle of 45° and 75 ml of 40% NaOH added so that it ran down the side to the bottom of the flask without mixing. 2 to 3 pieces of zinc metal were added and the flask immediately attached to the distillation apparatus. The heat was turned on to low and the contents of the flask swirled to mix. Distillation commenced and about 200 ml of the distillate was obtained in the receiving flask. The receiving flask was then lowered such that the receiving tube was above the level of the solution in the flask and detached from the apparatus. The distillate was titrated against standard acid until the blue colour disappeared. A blank was carried through the procedure but with no soil sample. The percentage nitrogen in the soil sample was calculated as follows:

% N =
Where T = sample titration (ml)
B = blank titration (ml)
N A = normality of acid used (to 4 decimal places)
S = sample weight (g)

2.8 Determination of Exchangeable Acidity

Apparatus

- Pipette
- Burette
- Centrifuge

Method

2.5g of the soil sample was weighed out and added to 20 ml of 1N of KCL. The mixture was

shaken for 1 hour in the mechanical shaker, after which it was put in the centrifuge to separate. 5 drops of phenolphthalein indicator was added to the resulting mixture and then it was titrated, using 0.02M of Sodium Hydroxide (NaOH). The acidity was calculated from the resulting titre value with this formula

$$\frac{\text{Volume of base x Normality of base}}{\text{weight of soil}} \text{ x 100 x Titre value}$$

2.9 Determination of Organic Carbon

The Walkley-Black (1934) method of determination of organic carbon was used.

Apparatus

- Volumetric flask
- 10 ml Pipette
- 50 ml burette.

Method

1 g of each sample was weighed and sieved into the volumetric flasks. Using the pipette, 10 ml of Potassium dichromate (VI) ($K_2Cr_2O_7$) was added to the flasks. The mixture was swirled for about 30 seconds to disperse the soil, then 20 ml of concentrated Tetraoxosulphate (VI) acid (H_2SO_4) was added to the mixture, using a graduated cylinder. The $K_2Cr_2O_7$ was added to separate the particles, while the H_2SO_4 was added to burn the particles to decompose. This same process was repeated in a flask which contained no soil. This was used as the "blank". The mixture was allowed to cool for 30 minutes, after which 5 drops of O-diphenylamine indicator was added. The resulting mixture was titrated with Ammonium Iron (II) sulphate as the base. The colour change observed was from green to brown.

The reaction which took place can be given as

Oxidation of Carbon:
$K_2Cr_2O_7 + H_2SO_4 \rightarrow K_2SO4 + Cr_2(SO4) + 4H_2O + 3O$ (x2)
$3C + 6O \rightarrow 3CO2$
$K_2Cr_2O_7 + H_2SO_4 + 3C \rightarrow 2K2SO4 + 2Cr2(SO4) + 8H2O + 3CO$

Titration

$FeSO_4\ (NH_4)_2\ SO_2\ 6H_2O \rightarrow FeSO_4 + (NH_4)_2\ SO4 + 6H2O$ (x2)
$2FeSO_4 + H_2SO_4 + O \rightarrow Fe_2\ (SO_4)_3 + H_2O$

The percentage organic carbon was calculated as

$$(\text{Blank} - \text{Titre}) \text{x normality of base x } 0.5 \text{ x } 100 \text{ x correction factor}$$

The total organic matter was derived by multiplying the organic carbon content by 1.724 (van Bemmelen factor)

2.10 Determination of Exchangeable Cations

This was used to determine the Ca, Na, Mg and K content of the soil samples.

Apparatus

- Measuring Cylinder
- Conical flasks
- Mechanical Shaker
- Centrifuge

Method

2.5 g of the soil samples was weighed into a 250 ml conical flask. 30 ml of Ammonium acetate (CH_2COONH_4) solution was added to the flask with the use of a measuring cylinder. The mixture was put in a mechanical shaker and allowed to shake for 1 hour after shaking, the mixture was filtered in a centrifuge. The filtrate was collected and transferred to McCartney bottles to determine the Na^+ and K^+ ions. This was achieved using a flame photometer. The Ca^{2+} and Mg^{2+} ions were determined by the aid of titration with EDTA as the base. For Ca^{2+} ions, 10 ml of the solution was separated and 10 ml of 20 % Potassium Hydroxide (KOH) was added to the separated solution. Calcin was used as the indicator. For Mg^{2+}, 10 ml of the solution was separated and 10 ml of NH^4 solution was added to it. 5 drops of elechrome Black T indicator was used as the indicator with the same EDTA as base.

2.11 Determination of Effective Cation Exchange Capacity

This was obtained by adding up the values of the exchangeable cations gotten (Ca^{2+}, Mg^{2+}, K^+ and Na^+) with the exchangeable acidity gotten. It is expressed in meq/ 100 g.

2.12 Determination of Base Saturation

The base saturation is obtained by adding the values of the base cations and dividing the

resulting figure by the Effective Cation Exchange Capacity and multiplying by 100 %

$$\frac{Sum\ of\ base\ cations\ (Ca+Mg+Na+K)}{Cathion\ Exchange\ Capacity} \times 100\ \%$$

3. RESULTS

3.1 Physicochemical Characteristics of the Soil

According to the results presented in in Table 1, the pH of the soil sample with *Taraxacum officinale* was neutral with a mean of 7.055 while that of the control soil was slightly acidic with a mean value of 6.72. The electrical conductivity levels of both soils were low. The sample containing *Taraxacum officinale* had a value of 0.49 ds/m while that of the soil without had a conductivity level of 0.87 ds/m. Soil with *Taraxacum officinale* had a higher organic carbon content of 0.78 % than that of the soil without *Taraxacum officinale* which had a percentage of 0.54 %. There was little difference in the total nitrogen content of both soils with values of 0.035 % for soil with *T. offiicinale* and 0.02 % for soil without *T. officinale*. Both soils had a relatively high amount of available phosphorus 87.04 ppm and 81.37 ppm for the soil with *Taraxacum officinale* and the sample without *Taraxacum officinale* respectively. Higher base saturation was observed in soil with *Taraxacum officinale* at 73.15%.

4. DISCUSSION

The results of this research showed a variation in some of the physiochemical properties of the soil samples studied. The high sand and low clay content of the soil with *Taraxacum officinale* possibly indicates a low aggregate stability of the soil and high porosity of the soil. The soil in which *Taraxacum officinale* was found had a neutral pH which corresponds with the writings of [11]. The percentage organic matter was relatively higher than that of the control soil. This may be due to the dense and strong taproot system [18] of the *Taraxacum officinale* plant, causing the compaction of soil and trapping of organic matter around the rhizosphere. The dense taproots of *Taraxacum officinale* may compete with shallow rooted plants for water.

The available phosphorus results of both soil samples were high. This may be as a result of the presence of manure or fertilizer, which may have been applied to the soil previously. *Taraxacum officinale* has been found to respond positively to high phosphorus levels, hence the justification for its spread around the area.

Table 1. Physicochemical Characteristics of the soil in the studied habitat

Parameters	Soil With *Taraxacum officinale*	Control (Without *Taraxacum officinale*)
Particle Size Analysis		
1.) Sand (%)	74.43	84.4
2.) Silt (%)	14.72	5.84
3) Clay (%)	10.85	9.76
Soil Textural Class	Loamy sand	Loamy sand
pH	7.05	6.72
Electrical Conductivity (S/m)	0.50	0.87
Organic Carbon (%)	0.78	0.54
Organic Matter (%)	1.35	0.93
Total Nitrogen (%)	0.04	0.02
Available Phosphorus (mg/kg)	87.04	81.37
Potassium (cmol/kg)	0.13	0.12
Calcium (cmol/kg)	1.60	2.72
Magnesium (cmol/kg)	0.60	0.40
Sodium (cmol/kg)	0.10	0.11
Exchangeable Acidity(cmol/kg)	0.83	2.20
Effective Cation Exchange Capacity (cmol/kg)	3.26	5.55
Base Saturation (%)	73.25	60.4

Zaprzalka and Peters [19] found that application of phosphorus up to 84 kg superphosphate, had an increasing yield of *Taraxacum officinale* when compared to where there was no application of superphosphate. The calcium levels observed in the soil with *Taraxacum officinale* was lower than that of the soil without. This justifies the report by Sweetster [20] that *Taraxacum officinale* can be used as indicators of soil which are low in Calcium. The low electrical conductivity of the soil may be ascribed to the inability of the soil to retain soluble salts within the rhizosphere.

The cation exchange capacity of the soil with *T. officinale* showed a lower value than the soil without it. According to [21] the cation exchange capacity of the soil is an indicator in the capacity of the soil to store nutrients. The reduction in value of CEC in the soil with *T. officinale* from the soil without it signals the influence of *T. officinale* on the CEC of the soil. The reduction in the value of Calcium cations and exchangeable acidity in soil with *T. officinale* and the resultant increase in base saturation value of the soil with *T. officinale* confirm the report of [22] that invasive plants just like pollutants may cause changes in the soil properties in the environment which favors the proliferation of the invasive species and drives native species into extinction.

5. CONCLUSION

Although *Taraxacum officinale* is considered difficult to control, because it spreads and grows rapidly, the results from this experiment showed that the plant poses some threat to the ecosystem especially the soil where it grows. This is because the results revealed some differences between the physico-chemical properties of the soil samples studied. However, the soil characteristics such as pH and calcium levels are suitable and have allowed the adaptation of *Taraxacum officinale* and encouraged its spread in the area. The soil dominated by this species can be considered low in fertility, due to its low cation exchange capacity which will make the soil unsuitable for native species to sprout.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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