ISSN: 0975-833X

Available online at http://www.journalcra.com

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

International Journal of Current Research
Vol. 14, Issue, 02, pp.20720-20725, February, 2022

DOI: https://doi.org/10.24941/ijcr.42979.02.2022

RESEARCH ARTICLE

TRIAL FOR THE INTRODUCTION OF WHEAT (*TRITICUM* SP) IN THE DALOA REGION OF CÔTE D'IVOIRE: AGRONOMIC CHARACTERIZATION OF FIVE ACCESSIONS

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ARTICLE INFO

Article History:
Received 14th November, 2021
Received in revised form
19th December, 2021
Accepted 24th January, 2022
Published online 28th February, 2022

Keywords:
Wheat, Accession, Chicken droppings, Treatment, Fertilizer, Côte d'Ivoire.

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ABSTRACT

The annual world production of wheat is approximately 758 million tons. In Côte d'Ivoire, the quantity of wheat imported is more than 550 000 tons. Wheat thus occupies an important place in the Ivorian diet. However, its cultivation is struggling to take off in the country because of climatic conditions unfavorable to its productivity. A study was initiated with the main objective of evaluating the agronomic characteristics of five wheat accessions and their resilience to climate change in west-central Côte d'Ivoire. Five wheat accessions, including three from Morocco obtained in Marrakech (AM), Tanger (AT) and Safi (AS); two from Nigeria (AN) and Côte d'Ivoire (AC). A completely randomized design was used with pots. Three treatments (T0, T1, T2) were applied to the 5 different accessions. The seedlings were sown on the same day in 5 dm^3 pots, filled with a substrate composed of soil and chicken droppings. The control pot (T0) was filled with 100% soil. T1 is filled with 20% chicken droppings for 80% soil. T2 was filled with 40% chicken droppings and 60% soil. The different organic manures of treatments T1 and T2 significantly increased the vegetative and production parameters of wheat. The effect of different treatments on grain production of wheat accessions showed significant difference with T2 treatment. Accession Nigeria had the highest number of spikes per plant (5.4) and spikelets per spike (27.5). It had the highest number of grains per spike (19.0). The highest grain filling rate (74.6%) of wheat was also observed with the same accession Nigeria for the same treatment T2. The effect of different treatments on grain production of wheat accessions was very highly significant ($p<0.001$). Of the five accessions evaluated (AM, AT, AS, AN and AC), only the AN accession was the most productive.

Citation: AYOLIE Koutoua, SORO Sibirina, SORO Dogniméton, KOUAKOU Koffi Abel and KOUADIO Yatty Justin. "Trial for the introduction of wheat (*Triticum sp*) in the Daloa Region of Côte d'Ivoire: agronomic characterization of five accessions.", *2022. International Journal of Current Research, 14, (02), 20720-20725.*

INTRODUCTION

The majority of cereals are grown for food or feed (Slama *et al.*, 2005). Cereal crops constitute about 30% of food energy sources in developed countries, compared to more than 50% in developing countries and even more than 90% in the poorest countries of Africa (CIC, 2008). Wheat, rice and maize are among the three most consumed cereals in the world. Wheat flour is used extensively in the manufacture of bread and pasta (Mac Key, 2005).

The generic term "wheat" refers to a group of cereals belonging to the genus Triticum. They are annual plants of the family Graminae or Poaceae. The annual world production of wheat is about 758 million tons (FAOSTAT, 2018). The world's largest producer is China (130 million tons) followed by India (99 million tons) and Russia (85 million tons). In Africa, its production is about 30 million tons (FAOSTAT, 2018). Two species of wheat dominate world production; these are soft wheat (*Triticum aestivum*) and durum wheat (*Triticum durum*). Wheat cultivation is adapted to a variety of soils and climates.

The existence of varieties adapted to different environments and resistant to many diseases allows wheat to be cultivated in many countries (Boutigny, 2007). In sub-Saharan Africa, the countries that are interested in growing wheat are Nigeria and Cameroon as opposed to Côte d'Ivoire (Boutrais, 2011). Agricultural production accounts for 33% of gross domestic product and 75% of export earnings. This agriculture is essentially based on industrial crops (wood, coffee, cocoa, cotton, rubber, oil palm, cashew nuts, pineapple) to the detriment of cereal crops. Among these cereal crops, wheat plays a very important socio-economic role (Tchamda & Thirion, 2013). However, wheat cultivation is struggling to take off in Côte d'Ivoire due to unfavorable climatic conditions and the lack of varieties adapted to its climate. This study was initiated to evaluate the agronomic traits of five wheat accessions to select those that can adapt to the climatic conditions of Côte d'Ivoire.

MATERIAL AND METHODS

Study area: This work was carried out on a plot of the University Jean Lorougnon Guédé, located in the city of Daloa in the center-west of Côte d'Ivoire (Figure 1). The city of Daloa is located between 6°53'38 north latitude and 6°27'0 west longitude and is part of the Haut Sassandra region. The vegetation, which used to be dense forest, has now disappeared in favor of various cash crops (Sangare *et al*., 2009). The soils are ferralitic. The climate is tropical. The average temperature is 27.5 °C with a rainfall between 1000 and 1500 mm of rain per year (Ayolié *et al*., 2016). The soil at the study site is predominantly ferralitic type (Dognimeton *et al*., 2015).

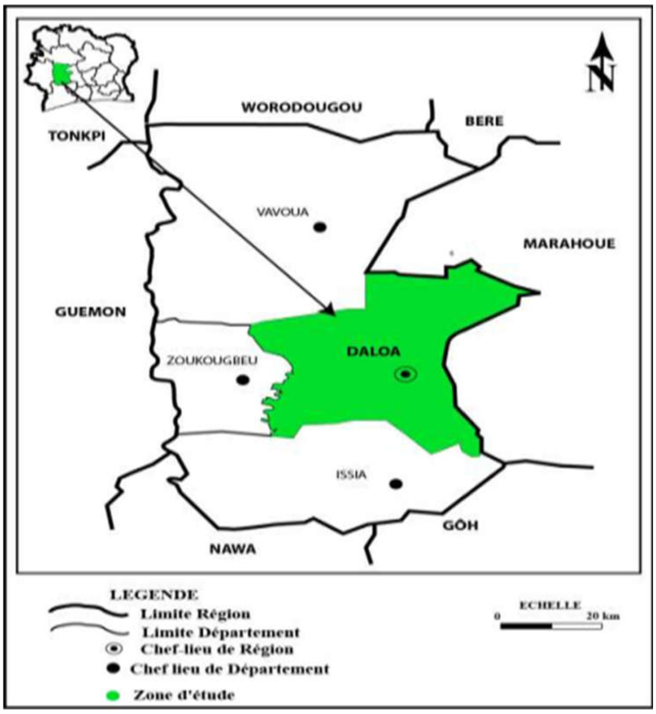
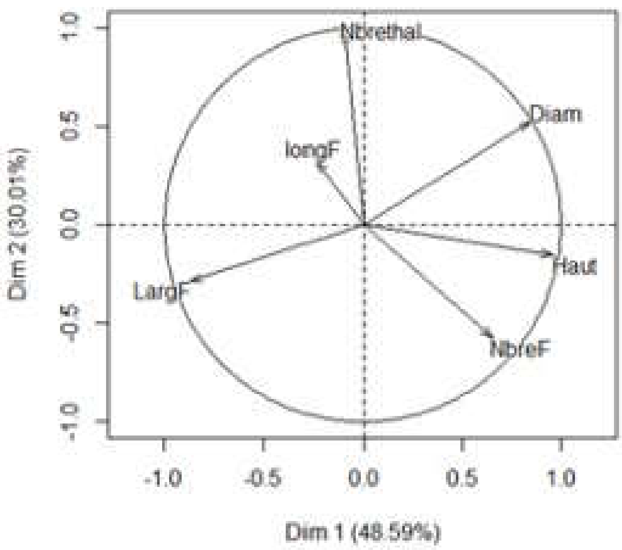


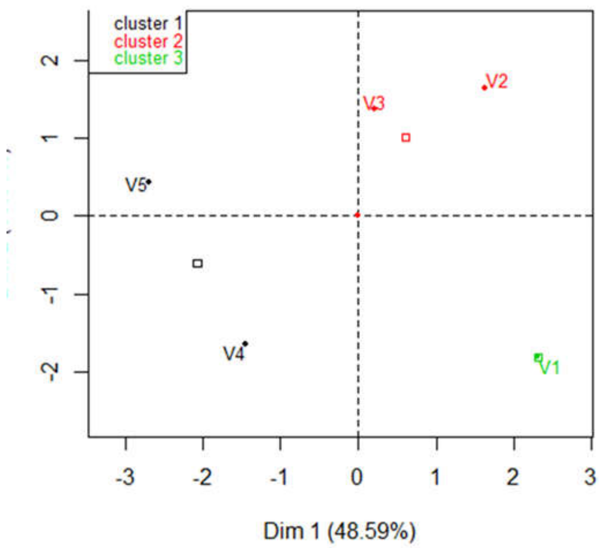
Figure 1. Presentation of the study area

Plant material : The plant material consists of five wheat accessions, three of which are from Morocco, from the cities of Marrakech (AM : accession Marrakech), Tangier (AT : accession Tanger) and Safi (AS : accession Safi). Two wheat accessions came from Nigeria (AN: Accession Nigeria) and Côte d'Ivoire (AC: accession Côte d'Ivoire) respectively.



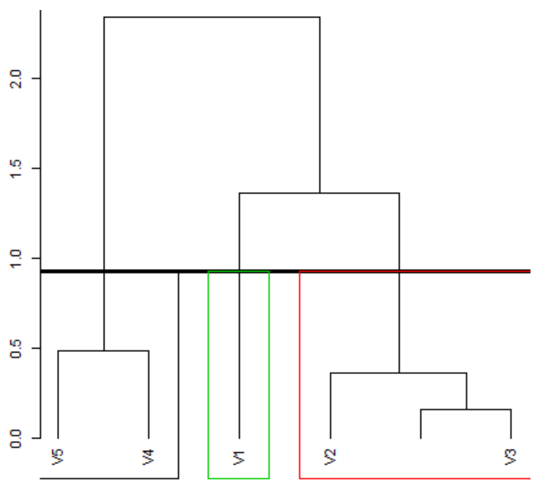
Plant height (Haut); Diameter at collar (Diam); Number of leaves (NbreF); Leaf length (LongF); Leaf width (LargF); Number of tillers (Nbrethal)

Figure 2. Projection of variables in the factorial plane



Marrakech (V1), Tangier (V2), Safi (V3), Cote d'Ivoire (V4) and Nigeria (V5) accessions

Figure 3. Projection of individuals in the factorial plane



Marrakech (V1), Tangier (V2), Safi (V3), Cote d'Ivoire (V4) and Nigeria (V5) accessions.

Figure 4. Dendrogram from the ascending hierarchical classification

Methods

Preparation of the substrate: A completely randomized design was used with 15 combinations including 5 wheat accessions. AM: Marrakech accession; AT: Tangier accession; AS: Safi accession; AC: Ivory Coast accession; AN: Nigeria accession and three treatments, T0, T1 and T2. Substrates composed of soil and chicken droppings in variable proportions were previously treated with a nematicide associated with a fungicide. The control pot (T0) was filled with 100% soil. T1 is filled with 20% chicken droppings for 80% soil. T2 is filled with 40% chicken droppings for 60% soil. The pots were perforated with 8 holes at 5 cm from the base and covered with a thin layer of gravel to ensure water and air drainage.

Parameters : Growth parameters are represented by plant height (HP) and plant diameter at crown (DC). Height was measured from the base of the stem to the point of spike insertion using a double decimeter. The average height was calculated using the following formula: Hm = Xi/Nt (1) where
Hm: Average height; Xi: Number of plants and Nt: Total number of plants. The diameter was measured at the base of the stem using a caliper. The average diameter was calculated using the following formula: Dm = n/Nt (2) where
n: Number of plants; Nt: Total number of plants per treatment and Dm: Average diameter. The number of leaves was determined by counting from germination to heading (NbF). The number of tillers was determined by counting on each plant. The number of spikes per plant was obtained by counting all the plants in the pot. The average number of spikes per accession and per droppings treatment was determined according to the following formula: Ne = n/Nt where

n: Number of ears per bucket; Nt: Total number of plants per treatment and Ne: Number of ears per pot. The filling rate was determined by the following formula: TRE = (NbG x 100)/NbEE where TRE: Spike Filling Rate; NbEE: Number of spikelets per spike and NbG: Number of seeds. The mass of ears (ME) and the mass of grains per ear (MGE) were determined using an electronic scale. Spike length was determined using a double decimeter. The number of spikelets per ear was determined by counting.

Statistical analysis: The data of different morphological and production parameters in relation to the effect of organic manure on wheat plants were processed with Statistica 7.1 software. Data were subjected to two-factor analysis of variance (ANOVA) at the 0.05 threshold. The FISHER LSD test was used for classification of significantly different means.
SPSS version 22.0 software was used at the 5% probability level to assess the factorability of the data collected through the calculation of the Kaiser-Meyer-Olkin (KMO) index and Bartlett's test of sphericity. A principal component analysis (PCA) followed by an ascending hierarchical clustering (HHC) was performed using R software version 3.5 to visualize the structuring of intra- and inter-accession variability. Data were summarized in tables and figures.

RESULTS

Growth and development of wheat accessions in relation to treatments: The growth and development of wheat accessions were studied.

Table 1 shows that the Marrakech accession presented the highest number of leaves at T1 fertilizer dose with a value of 7.1. The Nigeria accession presented the largest leaf length (22.8 cm). It was followed by the accessions of Marrakech and Tangier (21.4 cm), at doses T1 and T2. Analysis of leaf width showed that the Nigeria accession performed better at dose T2. The Safi (8.6) and Nigeria (9.1) accessions showed the best performance in tillering. The greatest plant heights were obtained with the accessions from Marrakech (49.1 cm) at dose T1 and Tangier (48.7 cm) at dose T2. The measurement of the diameter at the collar showed that the Tangier accession had the greatest value (1.63 mm), at dose T2. The growth and development of wheat accessions as a function of fertilizer doses were highly significant ($p<0.001$).

Effect of different treatments on grain production of wheat accessions: Table 2 shows the effect of treatments on the grain production of wheat accessions. The Tangier and Safi accessions were not able to enter into production during the whole observation cycle. The analyses concerned only the three accessions Marrakech (AM), Ivory Coast (AC) and Nigeria (AN). The number of spikes per pot revealed on these three accessions that the Nigeria accession had the highest number of spikes per plant (5.4) and the highest number of spikelets per spike (27.5) at the T2 rate (Table 3). The spike length of the Marrakech and Côte d'Ivoire accessions increased by 1.4 cm when the dose of chicken dung varied from 1 kg (T1) to 2 kg (T2). All associations, Marrakech (AM), Côte d'Ivoire (AC) and Nigeria (AN) showed the same ear mass at all doses (T1 and T2) of fertilizer. The Ivory Coast accession on the control substrate had the lowest ear mass (0.25 g). The highest number of grains per ear was found on the Nigerian accession (19) at dose T2. Accessions from Marrakech and Côte d'Ivoire gave the same number of grains per spike (16.1) with doses T1 and T2 respectively (Table 4). The highest grain filling rate of wheat was observed with the Nigerian accession at dose T2 (74.6%). The effect of different fertilizer doses on grain production of wheat accessions was very highly significant ($p <0.001$).

Correlation between characters of different accessions: Table 3 shows the correlation matrix between the different variables studied. The analysis shows a significant correlation (≥ 0.50) between the majority of the traits. The Kaiser-Meyer-Olkin index value of 0.618 gives good sampling precision and allows for principal component analysis to estimate the variability within the entire population of accessions studied. The highly significant Bartlett's test ($p<0.000$) confirms this possibility of analysis. Positive and highly significant correlations were observed between:

- Number of grains per spike and number of spikelets (0.83),
- Ear length and number of spikelets (0.75),
- Ear length and number of grains (0.68),
- Spike filling rate and number of grains (0.85),
- Plant height and crown diameter (0.68).

Structuring diversity using principal component analysis (PCA): Table 4 shows the eigenvalues of the PCA axes. It appears that 2 axes (Axis 1 and Axis 2) express respectively 48.59% and 30.01% of the variability, that is 78.60% of the total variability. These two axes were therefore retained for a better analysis of the agromorphological variability of the different accessions.

Table 1. Growth and development of wheat accessions in relation to fertilizer doses

Accession	Fertilizer Dose	Number of leaves	Length of leaves (cm)	width of leaves (cm)	Number of tillers	height of plant (cm)	Diameter at the neck (mm)
AM	T0	6,8±0,42^{ab}	19,8±1,78^{d}	0,60±0,12^{b}	3,5±1,00^{g}	47,7±8,15^{ab}	1,54±0,24^{bc}
AM	T1	7,1±0,66^{a}	21,2±7,36^{ab}	0,43b±0,05^{hg}	4,6±1,00^{f}	49,1±8,06^{a}	1,54±0,26^{bc}
AM	T2	6,4±0,46^{cd}	19,1±2,42^{e}	0,42±0,06^{h}	4,8±0,82^{f}	46,7±8,97^{cde}	1,48±0,26^{e}
AT	T0	5,7±0,47^{f}	19,4±1,90^{cde}	0,43±0,07^{hg}	7,9±2,66^{d}	44,4±8,51^{ef}	1,54±0,21^{bc}
AT	T1	6,5±0,50^{abcde}	21,4±2,43^{ab}	0,44±0,08^{hg}	8,6±2,47^{ab}	46,8±7,95^{bcd}	1,51±0,25^{cde}
AT	T2	6,6±0,59^{de}	20,0±1,92^{d}	0,47±0,12^{f}	8,7±1,34^{fab}	48,7±7,72a	1,63±0,21a
AS	T0	5,7±0,67f	19,2±0,11^{ec}	0,51±0,11^{f}	8,6±2,43^{ab}	43,7±9,06^{f}	1,47±0,26^{e}
AS	T1	6,3±0,45^{cd}	19,8±2,84^{d}	0,45±0,08^{g}	8,2±1,84^{c}	47,1±8,49^{bcd}	1,53±0,22^{bcd}
AS	T2	6,4±0,52^{cd}	19,5±2,49^{cde}	0,48±0,11^{ef}	8,5±1,53^{abc}	46,5±8,53^{bcd}	1,57±0,26^{b}
AC	T0	6,0±0,77^{ef}	17,8±0,13^{f}	0,49±0,13^{de}	3,6±1,27^{g}	43,5±7,35^{f}	1,39±0,19^{g}
AC	T1	6,4±0,58^{cd}	20,0±2,43^{d}	0,61±0,23^{b}	4,7±0,82^{f}	45,9±8,53^{ed}	1,50±0,25^{cde}
AC	T2	6,2b±0,62^{de}	19,6±2,18^{cde}	0,48±0,08^{ef}	4,7±0,79^{f}	45,4±9,61^{cd}	1,42±0,23^{gf}
AN	T0	6,1±0,84^{cdef}	20,0±3,01^{cd}	0,51±0,13^{ef}	9,1±1,18^{a}	43,7±10,02^{fe}	1,47±0,18^{def}
AN	T1	6,1±0,95^{def}	22,2±3,11^{b}	0,63±0,19^{gab}	8,3±1,78^{cd}	45,7±8,80^{bcdef}	1,35±0,16^{g}
AN	T2	6,5±1,16^{bcd}	22,8±3,95^{a}	0,65±0,17^{a}	6,5±2,25^{e}	44,7±8,17^{cdef}	1,52±0,21^{bcde}
P-Value		<0,000028	<0,000000	<0,000000	<0,00	<0,000254	<0,000000

AM : Accession Marrakech ; AT : Accession Tanger ; AS : Accession Safi ; AC : Accession Côte d'Ivoire ; AN: Accession Nigeria ; Values with the same letters are not significantly different (FISHER LSD test at 5%). P = Approximate Probability of Tests. Mean values are followed by their standard deviation (±). Control dose (T0) = 5 kg of soil without chicken droppings. Dose T1= 4 kg of surrounding soil +1 kg of chicken droppings and dose T2 = 3 kg of surrounding soil+2 kg of chicken droppings.

Table 2. Effect of treatments on ear production of wheat accessions

Accession	Fertilizer Dose	Number of spikes/plant (cm)	Ear length (cm)	Mass of ear (g)	Number of spikelets/ear	Number of grains/ear	Filling rate (%)
AM	T0	1,0±0^{c}	8,3±2,51^{d}	0,87±1,41^{a}	19,1±7,19^{b}	11,2±8,09^{cd}	41,2±26,52^{d}
AM	T1	1,0±0^{c}	10,1±1,93^{ab}	0,79±0,32^{a}	24,7±5,83^{c}	16,1±6,84^{ab}	50,1±20,46^{c}
AM	T2	1,0±0^{c}	9,7±1,94^{bc}	0,72±0,88^{a}	19,4±6,36^{b}	10,5±5,86^{d}	51,5±18,59^{c}
AC	T0	1,0±0^{c}	8,8±1,66^{d}	0,25±0,11^{b}	19,5±4,77^{b}	7,9±2,48^{e}	52,2±13,76^{c}
AC	T1	1,0±0^{c}	9,7±0,21^{bc}	0,69±0,20^{a}	22,8±5,66^{abc}	11,7±4,62^{dc}	52,7±12,13^{d}
AC	T2	1,0±0^{c}	10,2±1,90^{ab}	0,85±0,67^{a}	25,2±6,21^{c}	16,1±6,91^{ab}	61,6±15,48^{b}
AN	T0	2,5±0,97^{b}	11,5±0,82^{a}	0,87±0,19^{a}	24,4±5,59^{ac}	16,0±5,15^{abc}	64,0±8,87^{ab}
AN	T1	2,7±1,54^{b}	8,7±2,70^{cd}	0,55±0,44^{ab}	21,3±7,31^{abc}	12,3±7,64^{bcd}	64,4±20,69^{ac}
AN	T2	5,4±0^{a}	11,3±0,95^{ab}	0,95±0,02^{a}	27,5±4,21^{a}	19,0±1,47^{a}	74,6±12,47^{a}
P-Value		<0,001	<0,001	<0,001	<0,001	<0,001	<0,001

AM: Accession Marrakech ; AT: Accession Tanger ; AS: Accession Safi ; A : Accession Côte d'Ivoire ; AN : Accession Nigeria ; Values with the same letters are not significantly different (FISHER LSD test at 5%). P = Approximate Probability of Tests. Mean values are followed by their standard deviation (±). Control dose (T0) = 5 kg of soil without chicken droppings. Dose T1 = 1 kg of chicken droppings + 4 kg of surrounding soil and dose T2 = 2 kg of chicken droppings + 3 kg of surrounding soil.

Table 3. Correlation matrix between quantitative variables

	NEl/p	Ngr	NE/p	LEp	ME	TRE	LF	lF	NF	Dm	Ht	NTal
NEl/p	1.00											
Ngr	0.83	1.00										
NE/p	0.07	0.08	1.00									
LEp	0.75	0.68	0.12	1.00								
ME	0.29	0.38	0.04	0.29	1.00							
TRE	0.49	0.85	0.07	0.46	0.35	1.00						
LF	0.05	0.09	0.03	0.04	0.02	0.08	1.00					
Lf	-0.09	-0.06	0.03	-0.14	0.02	-0.03	0.22	1.00				
NF	0.01	0.02	-0.03	0.00	0.01	0.03	0.03	0.03	1.00			
Dm	-0.01	0.02	0.00	-0.01	0.06	0.04	0.16	0.19	0.01	1.00		
Ht	-0.03	0.00	-0.15	-0.02	0.05	0.02	0.14	0.18	0.03	0.68	1.00	
NTal	0.13	0.21	0.28	0.18	0.11	0.24	0.09	-0.09	0.06	0.12	0.09	1.00

Plant height (Ht); Ear length (LEp); Diameter at crown (Dm); Number of leaves (NF); Leaf length (LF); Leaf width (lF); Number of spikelets (NEl/pl); Date of appearance of female flower (Dfem); Number of spikes (NE/p); Number of grains (Ngr); Ear mass (ME); Filling rate (TRE); Number of tillers (NTal).

Table 4. Eigenvalues and contribution of the characters to axes 1 and 2 of the principal component analysis

	Axis 1	Axis 2
Eigenvalue	1,802	1,192
Total variance (%)	48,59	30,01
Cumulative total variance (%)	48,59	78,60
Characters defining the axes and their eigenvalues		
Haut	0,647	0,332
LongF	0,639	-0,140
Diam	0,619	0,303
NbreF	0,514	-0,479
Nbrethal	0,291	0,672
LargF	0,489	-0,536

Plant height (Haut); Leaf length (LongF); Diameter at the collar (Diam); Number of leaves (NbreF); Number of tillers (Nbrethal); Leaf width (LargF).

The examination of the coordinates of the variables recorded in this table shows that the variables that contributed to the elaboration of the first axis are the number of leaves (NbreF), the length of the leaf (LongF), the height of the plant (Haut) and the diameter at the neck (Dm). The second axis is defined by the width of the leaf (LargF) and the number of tillers (Nbrethal).

Projection of the variables on the correlation circle: The projection of the variables in the factorial plane revealed that they are mostly well represented (close to the circle) except for leaf length (longF) which is closer to the center of the circle. A variable has a representative quality if it is positioned on the circle or close to the circle. Furthermore, the level of the links between the different variables is represented by the geometric angles between the arrows. This confirms the correlations revealed by the correlation matrix previously established (Figure 2).

Projection of individuals in the factorial plane: The cloud of individuals in the factorial plane, suggests three main groups. The first group (cluster 1 in black color) is composed of accessions that are characterized by abundant tillering, with short and wide leaves. The second group (cluster 2 in red color) is composed of accessions with a large circumference at the collar. The third group (cluster 3 in green color) is made up of tall accessions with high biomass (Figure 3).

Diversity analysis by hierarchical ascending classification (HAC): The ascending hierarchical classification with truncation (0.9) was carried out to make the interpretation totally objective and to attest to the existence of well-defined and homogeneous groups. The three groups previously identified by the projection of individuals in the factorial plane are confirmed. Group 1 contains the Cote d'Ivoire (V4) and Nigeria (V5) accessions. Group 2 is composed of the Marrakech (V1) accession and group 3 is composed of the Tangier (V2) and Safi (V3) accessions (Figure 4).

DISCUSSION

The growth and development parameters of wheat (Triticum sp) plants varied according to the accessions and the growing medium. The accessions Nigeria, Marrakech, Tangier and Safi differed in height, diameter and number of leaves and spike mass. The Nigeria accession had the longest and widest leaves. The Marrakech accession had the tallest plants and the largest number of leaves. The Safi and Nigeria accessions had the best number of tillers. This difference in growth and development of these accessions would result from their ability to adapt to climatic conditions, and could also be genetic. These results are in agreement with those of Bahlouli *et al* (2005). They showed a significant difference between the growth of ten wheat accessions subjected to different cropping seasons. This difference would be related to the genetic material of the accessions. Fondio *et al*. (2013) and Zhani *et al*. (2015) showed in the vegetative development of different chili pepper accessions in Tunisia that this difference could be explained by the genotypic and environmental relationship. The treatments applied favored the development of the different wheat accessions. Treatments T1 and T2 resulted in good development of wheat accessions which is believed to be related to a favorable action of the mineral elements contained in chicken droppings. This result is similar to that of Mona *et al*. (2012) who showed that vegetative growth of plants is positively correlated with nutrient uptake. This is, in particular, nitrogen which plays an important role in increasing leaf indices and production. Shankara *et al* (2005) showed that poultry manure has a high value on yield because 60 to 90% of its phosphate content would be present in mineral form and thus directly available to the plant. Moreover, the significant difference obtained in production between the wheat accessions could be explained by their adaptability to the environment. The Nigerian accession showed a good vegetative development and a high grain filling rate. These results confirm those shown by Seleshi (2011), on the positive correlations between vegetative development and production components in chilli. The expression of the components in wheat as in other crops can be influenced by the genetic factors of each accession and climatic conditions (Lesage, 2011). Indeed, the higher the physiological activity in a plant the more it develops vegetatively and its yield is higher (Moreno *et al*., 2011). The high concentration of mineral elements (phosphorus and calcium) would contribute to the formation of long spikes (Quaggio, 2011). Hunsche *et al* (2003) showed that eggplant yield increased with the application of chicken droppings. Fill rate was significantly higher in fertilized buckets than in unfertilized buckets. Compost improves the yield of cereal plants (Fao, 2000). The result of the principal component analysis (PCA) applied to the five (5) accessions of wheat (*Triticum* sp) on the basis of the 6 morphological descriptors is a variance of 78.6% for the two axes. This variability is significantly higher than that observed by Kouakou (2019) and Djaha *et al*. (2017) in Côte d'Ivoire. Indeed, these researchers obtained a variability of 67.09% and 63.84% respectively for the first two axes cumulated with 50 maize mutants and 44 cassava accessions. This discrepancy could be explained on the one hand by the difference in crop types (wheat ≠ maize ≠ cassava) and by the site where the study was conducted on the other. The projection in the 1-2 plane of the principal component analysis (PCA), shows a distinct distribution of different accessions studied. This result attests to the existence of an inter-accession diversity of three (03) distinct groups that would represent important reservoirs of interesting traits for future generations. Groups 1, 2 and 3 include respectively low and high biomass accessions. Similar results were obtained by Alla *et al* (2018) after the analysis of 6 eggplant accessions grown in Côte d'Ivoire, identified 3 groups (community A, B and C) of eggplants that are characterized by better vegetative growth and average vegetative growth. Hierarchical ascending classification (HAC) was used to identify three groups, as was principal component analysis (PCA). Similar results were obtained by N'zué *et al*. (2014) by characterizing 159 cassava accessions from southwestern Côte d'Ivoire.

CONCLUSION

The Marrakech and Nigeria accessions proved to be more adaptive to a growing crop in Côte d'Ivoire. The growth and vegetative development of these accessions were more significant. The application of organic manure (chicken droppings) significantly increased plant growth and development as well as grain production of these wheat accessions. The application of chicken manure at the rate of 40% on was more effective on wheat grain yield for the Nigeria accession. This study shows that wheat cultivation can be adopted in the field in Côte d'Ivoire.

Declaration of Competing Interest : This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements

We are really grateful to REDAA ("Réseau de Recherche Développement sur l'Anacarde en Afrique") and COPABO ("Société Coopérative des Producteurs Agricoles de Bondoukou") for its help in rural area.

Statement of Credit Authors' Contribution

AYOLIE Koutoua and **SORO Sibirina**: Methodology, Supervision, Software, Formal Analysis, Resources, Data Retention, Research and acquisition of funding. **SORO Dogniméton** and **KOUAKOU Koffi Abel**: Project Administration, Conceptualization, Methodology, Resources, Data Retention, Supervision, Writing original project, Research and acquisition of funding. **KOUADIO Yatty Justin**: Methodology, Supervision.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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