Original Research Paper

Intercropping Agricultural Practices by Improving Maize Early Growth Process: A Bio-Statistical Approach

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Abstract: Fertile soil pressure represents a crucial concern *vis-à-vis* of agricultural crop yield improvement in several southern countries. Environmental concerns and soil low fertility as well as a rapid demographic development and as well intensive industrial exploitation with regard ground resource, drastically contribute in reducing agricultural land availability. We believe that multiple culture and/or intercropping experimentation designs, integration in southern countries agricultural practices, could partially overcame fertile soil pressure issues. The main types of intercropping include mixed intercropping, row intercropping and strip intercropping. Here we assessed maize/cowpea intercropping patterns as well as maize monoculture systems. For this purpose, experimental dispositive is as following; 5 parcels including sole maize plants, 5 parcels with alternation of maize and cowpea plots on the same row (strip intercropping) and 5 parcels including maize and cowpea alternation rows (row intercropping), by a computational statistical approach with the purpose to promote mixed crops practices in contrasting fertile soil availability concerns, optimizing maize plants growth process. Growth data (plant height and plant leave number) apropos 52 maize plants for each above described experimental sites were collected during 9 weeks and processed by own R script, including descriptive and analytical statistical surveys. Findings clearly shown a positive impact of intercropping practices in accelerating maize early growth process. Maize and cowpea rows intercropping exhibited a good performance in term of accelerating maize growth process as opposite to maize monoculture (p<0.03) and maize/cowpea strip intercropping parcels (p<0.001). This study highlighted the usefulness mixed cultures intercropping system based on maize/cowpea rows alternation planting pattern in improving maize early development and as well promoted experimental design as a valuable solution in agronomical research for contrasting agricultural concerns *vis-à-vis* of limited productive and as well low fertile ground resources.

Keywords: Maize and Cowpea Intercropping Patterns, Maize Monoculture

Introduction

The seeming increased competitiveness of intercropping systems makes them potentially useful for adoption into low input farming systems in which options for chemical weed control are reduced or non-existent (Szumigalski and Van, 2005). When two crops are planted together, intra and as well inter specific competition or facilitation between plants may occur (Zhang and Li, 2003). Then, Intercropping is the growing of two or more crop species simultaneously in the same field during a growing season. The intercropping of legumes with cereals offers

scope for developing energy-efficient and sustainable agriculture (Michael *et al.*, 2017). Previous research studies showed that mixtures of cereals and legumes produce higher grain yields than either crop grown alone (Olufemi *et al.*, 2001; Dapaah *et al.*, 2003). The yield increase is not only due to improved nitrogen nutrition of the cereal component, but also to other unknown causes (Connolly *et al.*, 2001). Several research studies highlight biological nitrogen fixation by grain legume crops (Izaurralde *et al.*, 1992; Giller and Cadisch 1995; Peoples *et al.*, 2002) and suggested the latter's as a significant nitrogen (N) source in agricultural ecosystems (Dakora *et al.*, 2000). However, investigations regarding nitrogen (N) fixation in complex cereal/legume crops mixtures are few (Stern, 1993; Peoples *et al.*, 2002). Furthermore, cereal/legume intercropping crop scheme and/or design patterns usually includes a legume which fixes N_2 that benefits the system and a cereal constituent that depends greatly on nitrogen, optimizing crop yield (Cochran and Schlentner 1995). Several experimental surveys have shown a significant direct transfer of fixed nitrogen (fixed-N) to the associated non legume species (Elgersma *et al.*, 2000; Chu *et al.*, 2004). Also, as previously suggested, several environmental concerns and soil low fertility as well as a rapid demographic development and intensive industrial exploitation with regard soil resource, drastically contribute in reducing agricultural land availability. Then, it appear evident that the purpose of mixing legume and cereals in the intercropping systems is to optimize the use of spatial, temporal and physical resources both above-and below ground, by maximizing positive interactions and minimizing negative ones such as competition among the components (Patrick, 2006). Several studies suggested that research should focused on manipulating the legume/cereal mixtures and establish different subsistence mechanisms that are used by the plants in stressed environments (i.e. northern area in Cote d'Ivoire). Also, hard work should be geared towards closing the current gap in rhizosphere research (Shaharoona *et al.*, 2006; Umesha *et al.*, 2014; Diarrassouba *et al.*, 2015; Noel *et al.*, 2016; Dago *et al.*, 2018) in mixed cultures by correctly outlining the unknown factors that affects plant growth in mixtures (Connolly *et al.*, 2001). This can lead to increased production through improved plant nutrition, as well as genetic manipulation of different plant species and management practices in the cropping systems (Patrick, 2006). Moreover, numerous studies mainly exhibited legume/cereal intercropping mixtures in agricultural practices as an eco-friendly approach for reducing weed problems *via* non chemical methods by improving crops yield. Indeed, several studies exhibited intercropping maize and cowpea in different patterns and mix-proportions as affecting grain yield due to competition between the pair crops compared to individual cropping (Yilmaz *et al.*, 2007; Dahmardeh *et al.*, 2009; Takim, 2012). Also, our recent studies suggested statistical

models as adequate systems in assessing experimental agriculture performance (Dago *et al.*, 2015; 2016; 2018). Usually, experimental design in agronomic studies generate heterogenic as well as big data size allowing computational statistical tool integration in that data analysis procedure (Dago *et al.*, 2016; Noel *et al.*, 2019). Forecasting of crop yields is a formidable challenge (Dago *et al.*, 2018). The main factor affecting crops yield are soil characteristic, crop-inputs supplies and weather experience by the soil crop during growth period. Quantitative data on these factors forms one approach for forecasting crop yields. The other approach uses plant vigor measured either through plant characters or through remotely data. Also, soil properties are greatly influenced by climatic conditions. These effects are manifested through crop stand, number of tiller, number of leaf, root and plantlet length, leaf area etc. which ultimately determine crop yield. Then several studies discussed statistical methodologies such as linear regression model and principal component regression (Jain *et al.*, 1984; Chandrahas *et al.*, 1989) and as well probability model based on Markov Chain (Jain and Agrawal, 1992) for crop forecasting using plant metrics parameters. Here we performed a multivariate bio-statistical analysis with the purpose to highlight and promote maize and cowpea cereal intercropping experimental schemes and/or experimental designs paying attention to maize cereal early growth performance, in a low fertile soil and/or agro-climate as well as high pressure agricultural area, northern of Cote d'Ivoire (Diarrassouba *et al.*, 2015). The present survey partially based on our recently developed computational statistical pipeline (Noel *et al.*, 2019) implemented in R programing environment (Core Team, 2018).

Materials and Methods

Experimental Design

The experiments were conducted over a period of 9 weeks from June, 2017 to September, 2017, corresponding to the long rainy season at botanical garden in Péléforo Gon Coulibaly University (UPGC), in Korhogo (Latitude: 9°26 'North, Longitude: 5°38' West) in northern of Cote d'Ivoire. The climate in this area is characterized by two types' Sudanese seasons; (i) dry season, from November to April, punctuated by Harmattan (dry wind from the Sahel) and (ii) rainy season from June to November. The climate of the area is the maritime sub-equatorial with average temperatures that range of 24°C-33°C and total annual rainfall that range of 1100-1600 mm (Diarrassouba *et al.*, 2015). The experiment was randomized complete block design with 5 replications in three different experimental schemes and/or designs as following; (i) parcels including maize monoculture referred as intercropping system 1 (IS1), (ii) parcels with alternation of maize and cowpea

plots on the same row (strip intercropping), named intercropping system 2 (IS2) and (iii) parcels with alternation of maize and cowpea row (row intercropping), referred as intercropping system 3 (IS3) (Fig. 1). Each elementary parcel is made up of 5 lines, each with 12 pockets with gaps of 0.80 m between the lines and 0.5 m between the pockets on the same line (Fig. 1). Taking together our experiment included 15 elementary plot for the entire device. Then, experimental site area has been estimated around 400m² (20m×20m). Next, plowing and leveling and picking were done few days before sowing. It is noteworthy to underline that maize and cowpea seeds were previously treated with fungicides before sowing. Sowing was carried out in pockets (4 grains per pocket). Once plants emerged, plants pair off for each considered pocket was performed about 15 days later. Weeding was done regularly throughout the cycle and NPK intake was done during vegetative phase. So, each maize and/or maize/cowpea pair plot received 25kg.h^{-1} of NPK and as well urea at sowing.

Maize Growth Features Data Collection and Data Pre-Treatment And/Or Pre-Processing

The present survey aims to assess maize early growth features performance in two (2) cereal/legume intercropping pattern schemes referred as strip intercropping and row intercropping and as well in maize monoculture experimental designs. The experiment was conducted in a randomized complete block design with each block of treatments replicated five (5) times. We collected, maize plants height and leaves number data with regard 52 plants for each processed intercropping pattern systems as well as maize monoculture plot (Fig. 1). Indeed, 52 maize plants *via* a simple random sampling method were selected in the previous described 15 elementary plots (Fig. 1). Growth parameters were evaluated using a centimeter as scale of measurement (cm). Maize plants height have been measured from the ground level to the end of the longest petiole.
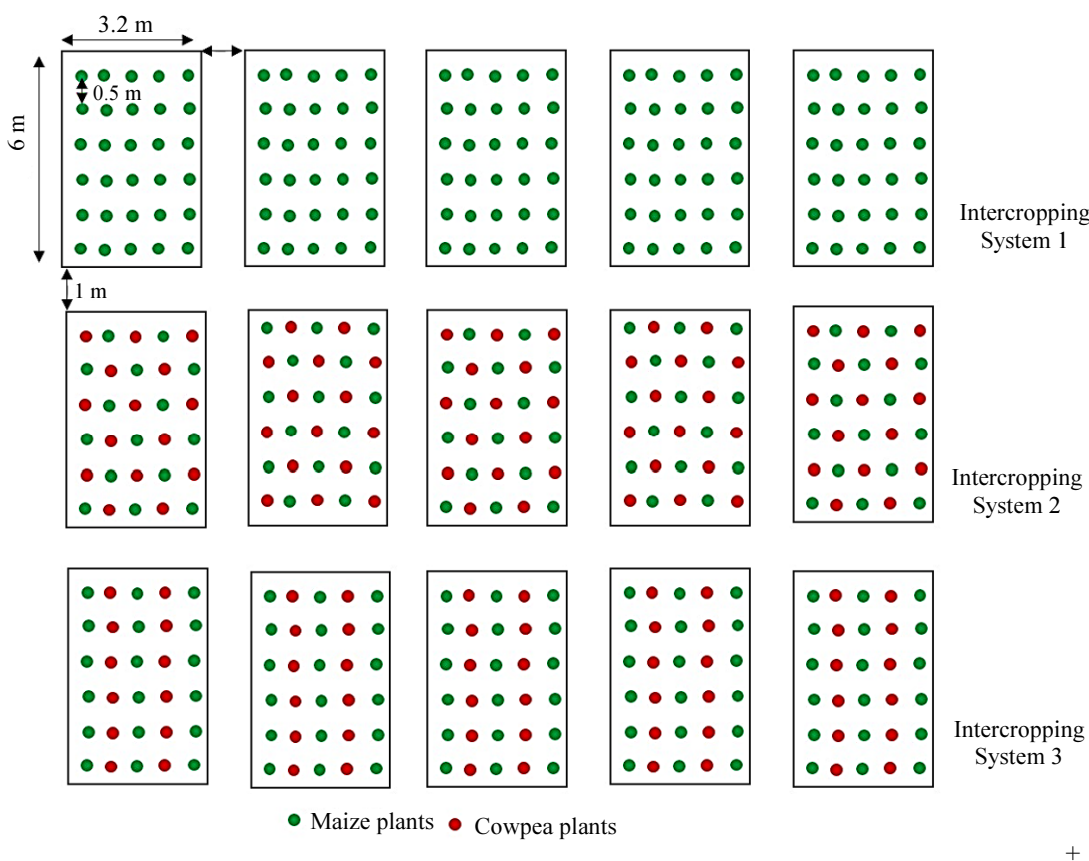

Fig. 1: Illustration of experimental design including the 15 elementary experiences: five (5) parcels including maize monoculture (Intercropping System 1: IS1), five (5) parcels with alternation of maize and cowpea plots on the same row (Intercropping System 2: IS2) and five (5) parcels with alternation of maize and cowpea row (row intercropping; Intercropping System 3: IS3)

Also, maize leaves number per plant was counted weekly. Maize growth features data have been collected through nine (9) weeks and summarized as following: (i) plants height and leaves number collected data during week 1, 2 and 3; (ii) plants height and leaves number recorded during week 4, 5 and 6 and plants height and leaves number data collected from week 7, 8 and 9. We performed maize growth features data normalization (maximum normalization) before statistical analysis aiming to reduce that data variability bias. It is noteworthy to underline that in statistics, normalization refers to the creation of shifted and scaled versions of statistics, where the intention is that these normalized values allow the comparison of corresponding normalized values for different datasets (heterogenic data) in a way that eliminates the effects of certain gross influences, as in an anomaly time series (Dodge 2003; Dago *et al.*, 2015).

Computational Statistical Analysis

The statistical analysis was carried out using R software (version 3.5.1). For this purpose several R package and/or libraries such as "gplots", "corrplot", "qgraph", "sem", "psych", "vioplot", "nFactors" and "ape" and "ggplot2" have been installed and loaded in R programing environment and/or console by applying *library()* function. Descriptive statistic englobed Pearson correlation and as well Euclidean distance of Pearson correlation heat-map and phylogenetic clustering graphics via *heatmap.2 ()* and *plot (as.phylo ())* script and/or function respectively. This analysis also included maize growth features variance clustering analysis by running above mentioned *heatmap.2* R function. Also, we performed a multivariate statistical survey based on R fitting curve analysis. Indeed, R software curve fitting function (Sandra, 1994; William, 1984) which is the process of constructing a curve, or mathematical function, that has the best fit to a series of data points (Halli and Rao, 1992), possibly subject to constraints. Interestingly, fitted curves can be used as an aid for data visualization (Halimah *et al.*, 2009; John, 2009) to summarize the relationships among two or more variables (Sandra, 1994). So, all analyzed statistical parameters curve in the present survey have been fitted by maize growth parameters (plant height and plants leaves number) in processed Intercropping System 1 (IS1). Maize growth features data distribution function were realized by R *plot(ecdf())* function for each considered intercropping experimental site by assessing maize weekly growth development dynamism, while both multivariate boxplot and as well Principal Component Analysis (PCA) graphics, were generated with the purpose to visualize maize growth data features variability (variance). The biplot provides a useful tool for data analysis and allows for the visual appraisal of the structure of large data matrices. It is especially effective in principal component analysis, where the biplot can show inter-unit distances and indicate clustering of units as well as display variances and correlations of the variables (Gabriel and Odoroff, 1990). Here we used biplot for the clustering of week 1-3, week 4-6 and week 7-9 factors basing on maize growth features variance. Analysis of variance (ANOVA) for linear model fit, compute an analysis of variance table for the three processed intercropping systems (IS1, IS2 and IS3) linear model fits *via* the following script: *anova (object, ..., scale = 0, test = "F")*. Results table will contain F statistics and P values comparing the mean square for the row to the residual mean square. The comparison between our three intercropping schemes models will only be valid if they are fitted to the same dataset (Chambers, 1992). A crucial decision in exploratory factor analysis is how many factors to extract. Parallel analysis in principal component analysis is a useful method to established the number of principal component needed in a multi-variant statistical analysis (Franklin *et al.*, 1995) in which theoretical estimate variance is computed and compared to observed (real variance) or experimental data. The output file of this analysis is a scree graph. So, the "*nFactors*" package offers a suite of functions to aid in this decision (Zwick and Velicer, 1986). Next, we evaluated relationship between maize plant height and leaves number parameters for each considered week intervals (week 1-3, week 4-6 and week 7-9) in the three (3) processed maize/cowpea intercropping experimental sites by parallel PCA survey in detecting needed components. Inferential and/or analytical statistical analysis with regard presently performed bio-statistical survey consisted in one sample statistical test and as well Fisher test in comparing maize growth features data variance differences.

Results

Pearson Correlation and Variance Analysis Weighing Maize and Cowpea Intercropping Culture Systems Concordance and Dynamism

Pearson correlation survey exhibited parcel and/or culture system preeminence regardless processed maize plants growth features (leaves number and plants high) as well as data collection periods (Fig. 2A). Also, findings revealed a high intra-correlation coefficient between maize growth features in intercropping systems 2 and 3 (IS2 and IS3) in comparison to experimental scheme including maize monoculture (Fig. 2). Further, the same survey suggested a relative good agreement ($R^2 = 0.32$, $p \ll 0.05$) between intercropping schemes 2 and 3 (IS2 and IS3) in assessing maize plants growth process as opposite to intercropping system 1 ($R^2 = 0.19\text{-}0.23$, $p < 0.05$) (Fig. 2A).
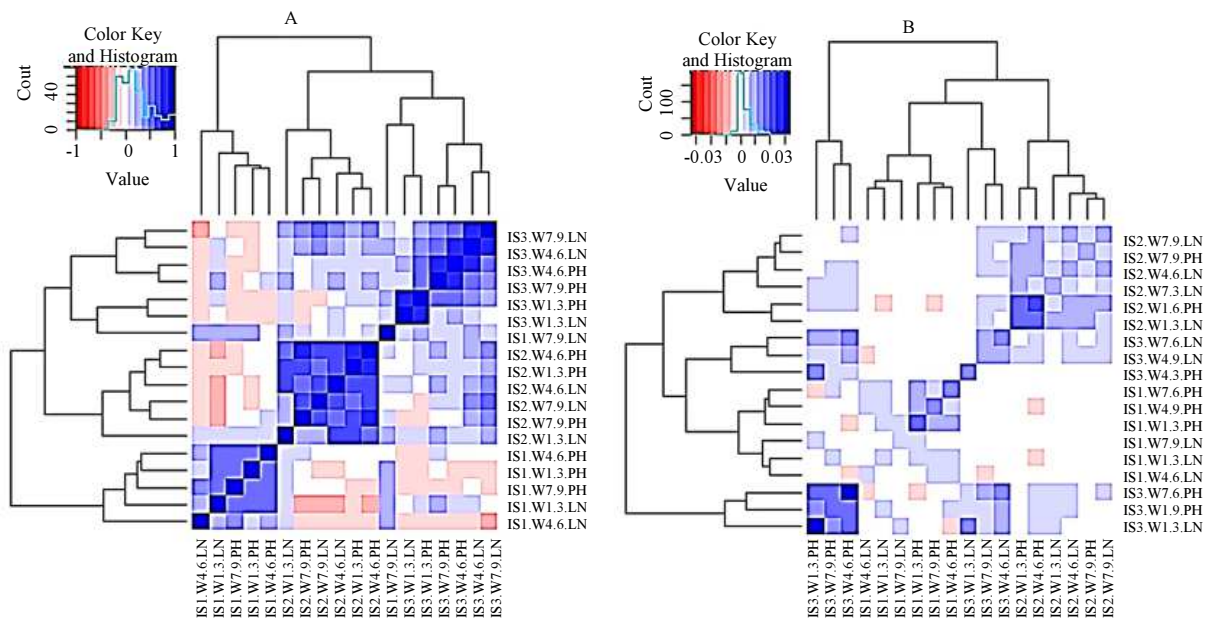
Fig. 2: (A) Pearson correlation and (B) variance relationship heatmap graphs in evaluating maize monoculture parcels (Intercropping System 1: IS1) and parcels with alternation of maize and cowpea plots on the same row (Intercropping System 2:IS2) and mixed cropping scheme with alternation of maize and cowpea rows (Intercropping System 3: IS3) concordance by evaluating maize plants growth features (leaves number and plants height) performances. i.e.: IS3.W1.3.LN acronym refers to maize Leave Number features collected in maize/cowpea Intercropping Scheme 3, during week 1-3 interval, while IS3.W1.3.PH acronym indicates maize Plants Height features collected in maize/cowpea Intercropping Scheme 3 during week 1-3 interval period.

Table 1: One sample statistical test assessing IS2 and IS3 maize and cowpea intercropping systems by assuming maize experimental parcel (IS1) as benchmark and/or reference (df = 311).

	Maize intercropping system 2 (IS2) vs. Maize culture system (IS1)	Maize intercropping system 3 (IS3) vs. Maize culture system (IS1)
p	0.05[**]	0.00[***]
Mean value of maize features (leave number and plant height)	0.78	0.73
Confidence interval (95%)	0.76-079	0.71-0.75
Statistical test power coefficient (t)	-2	-6.75

[***] p≤0.05

Interestingly, parcels with alternation of maize and cowpea rows (IS3) appear more heterogenic site in term of Pearson correlation values, when compared to the intercropping schemes 1 and 2 (Fig. 2A). Remarkably, variance graphic survey confirmed parcels with alternation of maize and cowpea rows (IS3) dynamism especially for processed maize plants height features as opposed to parcels with alternation of maize and cowpea plots on the same row (IS2) (Fig. 2B). Descriptive and analytical statistic test (one sample statistical test) assuming maize parcel (IS1) as benchmark, confirmed previous observed intercropping systems performance differences by assessing maize plants growth parameters and suspected a high growth performance of maize in parcels with alternation of maize and cowpea rows (Table 1).

Multivariate, R fitting and Principal Component Statistical Survey Estimating Maize and Cowpea Culture Intercropping Systems Dynamism

In this chapter we performed several descriptive and analytical statistical analysis with the purpose to evaluate maize and cowpea experimental parcel intercropping schemes performances. Statistical distribution function curves referred to processed experimental intercropping sites proposed intercropping system 3 (IS3) as exhibiting the highest dynamism in term of maize plants development (growth) as opposed to intercropping system 1 and 2 (Fig. 3A, B and C). Boxplot multivariate statistical survey (Fig. 3D) showed higher data variance and/or variability evaluating maize plants growth features in experimental parcel with alternation of maize and cowpea rows (IS3) in comparison to both intercropping schemes 1 and 2 (IS1 and IS2).
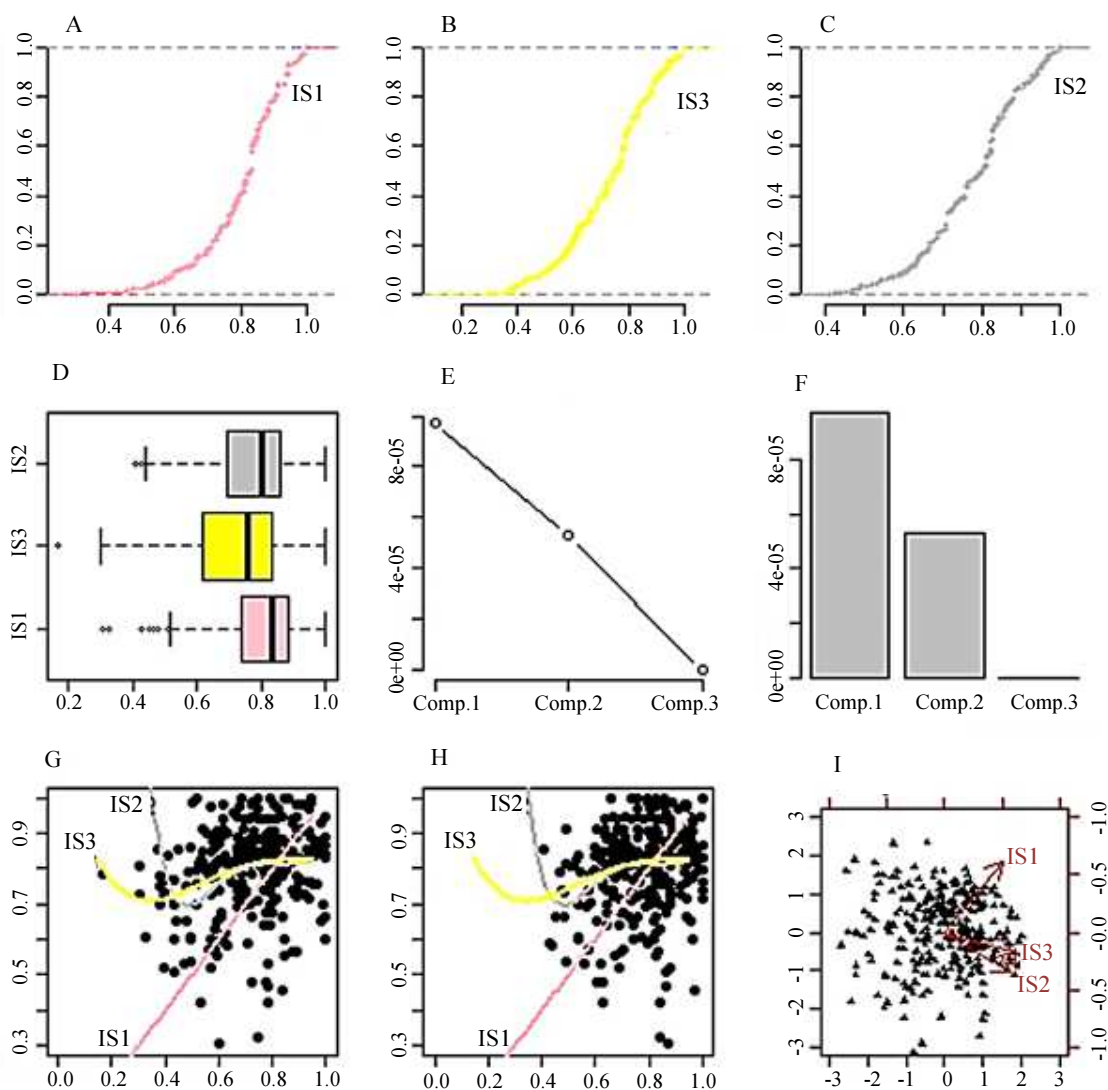
Fig. 3: (A), (B) and (C) distribution functions of maize leave number and height features data by processing IS1, IS2 and IS3 maize/cowpea intercropping schemes. (D): boxplot multivariate survey assessed maize/cowpea intercropping parcels maize growth data features distribution. (E) and (F): IS1, IS2 and IS3 intra-parcel variance estimation. (G) and (H): R fitting curve survey in evaluating IS1, IS2 and IS3 maize/cowpea intercropping planting design pattern mathematical relationship. (I) Biplot PCA graphic highlighted maize plants population data dispersion by processing two components in assessing maize/cowpea intercropping planting systems dynamism.

Table 2: Fisher test comparing variance differences between IS1 and both IS2 and IS3 maize and cowpea intercropping experimental parcel (df = 311).

	Maize/cowpea intercropping system 2 (IS2) vs. Cropping including maize culture only (IS1)	Maize/cowpea intercropping system 3 (IS3) vs. Cropping including maize culture only (IS1)
p	0.85[NS]	0.00[***]
Variance ratio difference	0.98	0.62
Confidence interval (95%)	0.78-1.22	0.5-0.77
Statistical test power (F)	0.98	0.62

[***]p<0.005 and [NS] p>0.05

In addition, variance differences (component 1> component 2> component 3) between analyzed maize/cowpea intercropping systems have been supported by presently performed principal component analysis (Fig. 3E and F). Next, we focused our attention in evaluating the mathematical relationship between IS1, IS2 and IS3 maize/cowpea intercropping agricultural schemes by an R fitting curve survey. Interestingly, results with regard that survey displayed high growth performance of maize plants in IS3 intercropping system as opposed to maize in IS2 experimental scheme when IS1 intercropping system was assumed as reference (Fig. 3G and H). Variance analysis suspected high variability (high dynamism in maize plants growth process) with regard both IS3 and IS2 maize and cowpea intercropping agricultural systems as opposite to experimental site including sole maize crop (Fig. 3E and F). Remarkably, dispersive attitudes with regard IS3 and IS2 maize/cowpea intercropping agricultural systems were confirmed by biplot principal component survey (Fig. 3I). These results suggested a relative concordance between parcels with alternation of maize and cowpea plots on the same row (IS2) and parcels with alternation of maize and cowpea rows (IS3) in improving maize culture development and/or growth dynamism. Fisher statistical test in comparing analyzed maize and cowpea intercropping systems, highlighted a significant variance ratio difference ($p < 0.05$) between parcels with alternation of maize and cowpea rows (IS3) and maize cropping scheme (IS1). Further, the same survey exhibited no significant difference between IS2 and IS1 maize and cowpea intercropping systems (Table 2). Considering as a whole, the present multivariate statistical survey suspected a rapid growth of maize plants in parcels alternating maize and cowpea rows (row intercropping).

ANOVA Survey in Comparing Intercropping Schemes Performance by Processing Maize Leave Number and Plant Height Growth Features

Here, we analyzed separately processed maize growth parameters (maize plant height and maize plant leaves number). Analysis of variance concerning both processed maize growth features in the different intercropping experimental sites (IS1, IS2 and IS3) showed a good performance (Fig. 4) of parcels with alternation of maize and cowpea rows (IS3) when compared to parcels with alternation of maize and cowpea plots on the same row (IS2) ($p < 0.001$) and to experimental site including sole maize crops (IS1) ($p < 0.0001$). Also, the present analysis by comparing maize plants growth features in IS1, IS2 and IS3 intercropping experimental sites suggested high confidence interval and/or high variance variability for maize plants height growth parameter (Table 3). However, it is noteworthy to underline that global ANOVA test performed on maize plants height and as well leaves number growth features, suggested a strong significant difference ($p \ll 0.05$) with regard variance parameter, by processing IS1, IS2 and IS3 maize/cowpea intercropping experimental sites (Table 3). Taking together, this survey suggests the propensity of parcels with alternation of maize/cowpea rows (IS3) in accelerating maize plants growth process.

Performance Assessment of Pearson Correlation Coefficient between Maize Growth Features in Maize/Cowpea IS3 Intercropping Scheme

Here we focused on maize plant development in parcels with alternation of maize and cowpea plants rows (IS3 intercropping system), since previous results exhibited that intercropping scheme as improving and as well accelerating maize early growth process (Fig. 3 and 4). The present Pearson correlation analysis (Fig. 5) accorded preeminence to collected growth features data recorded during week 1-3 interval (Fig. 5B) by exhibiting the highest correlation between maize plants height and leaves number parameters ($R^2 = 0.8$) as opposed to maize growing features data collected during week 4-6 and week 7-9 intervals. Also, the same analysis displayed a significant high correlation ($R^2 > 0.75$, $p < 0.05$) between processed maize plants height and leave number features for the first seven (7) weeks (Fig. 5A).

Table 3: ANOVA table by comparing IS1, IS2 and IS3 maize/cowpea intercropping experimental schemes in supporting maize plants development.

Maize plant height				Maize leave number		
No difference	Estimated Difference	SD	p	Estimated Difference	SD	p
IS2-IS1 ==0	-2.05	0.62	0.003[**]	-0.12	0.07	0.18[NS]
IS3-IS1==0	2.01	0.61	0.003[**]	0.23	0.06	0.002[**]
IS3-IS2 ==0	4.06	0.7	<0.001[***]	0.35	0.08	<0.0001[***]

p=0.00 for ANOVA global test by analyzing maize plant height and leave number growth features in the three processed maize and cowpea intercropping systems. SD: standard deviation. [***] p<0.005 and [NS] p>0.05
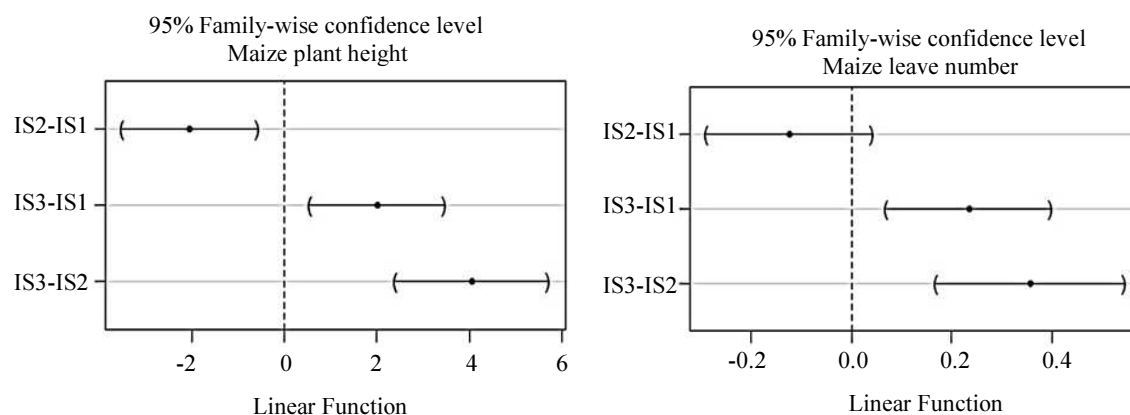
Fig. 4: ANOVA linear function measuring maize plant height and leaves number features variance difference, by processing IS1, IS2 and IS3 maize/cowpea intercropping design planting patterns experimental sites.
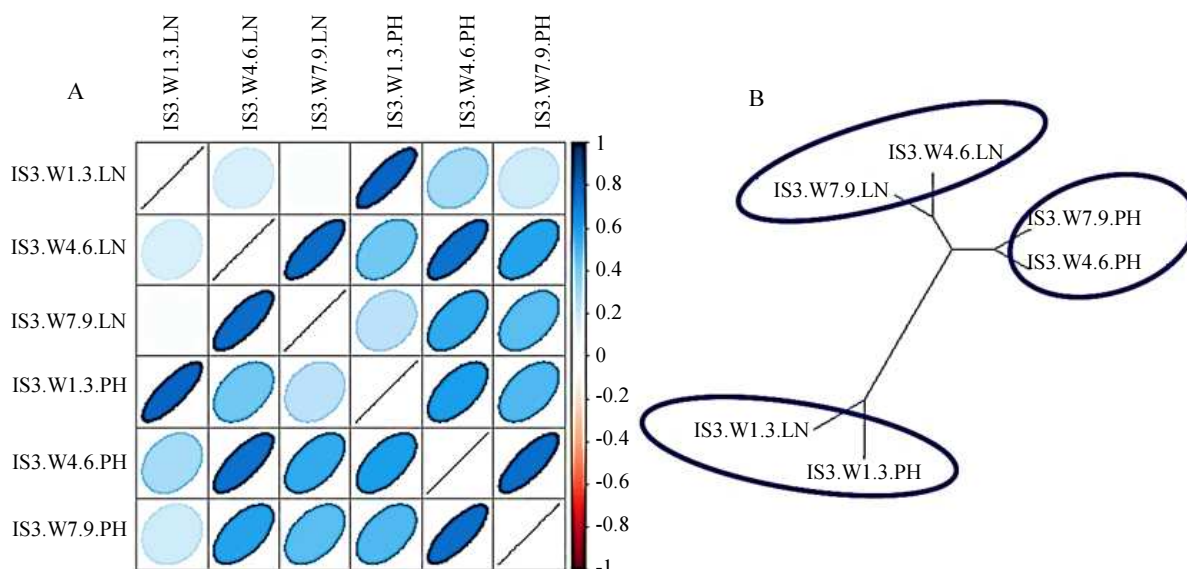

Fig. 5: Pearson correlation analysis measuring maize growth parameters concordance in maize/cowpea intercropping plating design pattern based on maize and cowpea rows alternation scheme (Intercropping System 3: IS3) assessing maize plants growth process.

Interestingly, phylogenetic tree referred to Euclidian distance of Pearson correlation confirmed non-significant difference between plant growth features after the seventh week (Fig. 5B). So, findings suspected maize plant growth process during the first three week as a period normalizing the relationship between plants height and plants leave number features (Fig 5A and B). Indeed, correlation among plant height and plant leave number resulted to be higher ($R^2 = 0.8$) for week 1-3 interval in comparison to the other considered week intervals ($R^2 = 0.75$ for week 4-6 and $R^2 = 0.46$ for week 7-9) (Fig. 5B). These results suggested a slowdown in maize leaf germination after the third week. Interestingly, maize plants leaf germination

slowdown is accentuated ($R^2 = 0.8 > R^2 = 0.75 > R^2 = 0.46$) with the growth of the plants (Fig. 5B). In the other word, our survey supported inverse relationship between maize plant growth and leaf germination.

Parallel Principal Component Analysis (PCA) Discriminating Component Number in Explaining Maize Data Variability in IS3 Intercropping Site

A crucial decision in exploratory factor analysis is how many factors to extract. Parallel analysis in PCA survey is a useful method to established the number of principal components and/or factors needed in a multi-variant

statistical analysis in which theoretical estimate variance is computed and compared to observed (real variance) or experimental data. The output file of our analysis is a scree graph (Fig. 6), where two components and/or factors displayed observed variance (black dots) higher than theoretical variance (yellow dots) (Fig. 6B). In the other word, presently parallel PCA survey findings discriminated 2 factors as statistically significant in explaining and/or justifying presently processed data dispersion and/or dynamism (Fig. 6). Also, parallel principal component analysis suggested these two factors (components 1 and 2) Eigen values higher than established theoretical mean value (Fig. 6A). Then, the present survey supposed two optimal coordinate as suitable (Fig. 6A) for the subjacent maize growth features data dispersion analysis.

Multivariate Analysis Assessing IS3 Intercropping Experimental Site Performance by Maize Growth Features Data Dispersion

We focused here on data dispersion for each considered maize plants growth parameters with the purpose to highlight weekly plant development processes dynamism. The present multivariate statistical survey clearly exhibited maize plants height growth features data collected during week interval 1-6 as the main source of that data variability (Fig. 7). Interestingly, this result displayed a consistent agreement with above performed parallel principal component analysis (PCA) that predicted two factors in explaining maize growth features data variability in IS3 intercropping site. So, merging the present results (Fig. 7) with those of previous parallel PCA analysis (Fig. 6), suggested maize plant height features recorded during both week 1-3 (IS3.W.1.3) and 4-6 (IS3.W.4.6) intervals as satisfactory factors explaining maize plants development dynamism in IS3

intercropping experimental site. In addition, Fisher test shown a significant difference ($p << 0.05$) in term of variance comparison between maize height growth features dynamism referred to both week 1-3 (IS3.W.1.3) and 4-6 (IS3.W.4.6) intervals and the other's processed maize growth parameters (maize plant height and as well maize leaves number) collected during week 1-3 and 4-6 and 7-9 intervals (Table 4). Also, it is noteworthy to underline that the present multivariate analysis supposed the high susceptibility of maize plants height component in reacting to IS3 intercropping scheme stimulus as opposed to maize plant leave number feature (Fig. 7).

Performance Assessment of the Relationship between Maize Growth Parameters in Maize/Cowpea Intercropping by Processing Detected Parallel PCA Survey Factors

The present network relationship survey clearly displayed maize plant height parameter during both week 1-3 and 4-6 intervals as main sources of maize growth data variability (Fig. 8A). Standard deviation associated to that week intervals are 0.15 and 0.26 respectively. Proportion of variance with regard maize plant height features explained by week interval 4-6 (component 1); 0.58 is higher than those explained by week interval 1-3 (component 2); 0.37. Then, component 1 and component 2 of the present PCA network survey exhibit a cumulative proportion of variance around 0.95. Our analysis revealed a feeble impact (proportion of variance = 0.04) of maize plant height feature during week interval 7-9 (component 3) in explaining maize development dynamism (Fig. 8A) in the present analyzed maize/cowpea intercropping scheme (IS3).
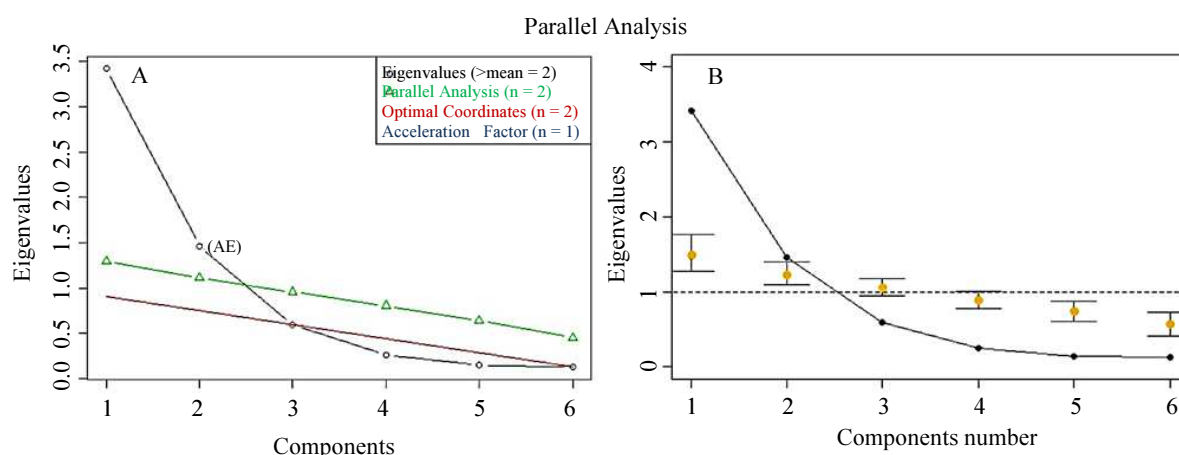

Fig. 6: Parallel Principal Component Analysis (PCA) evaluating component number (s) and/or optimal coordinate (s) suitable for maize growth feature data dispersion survey
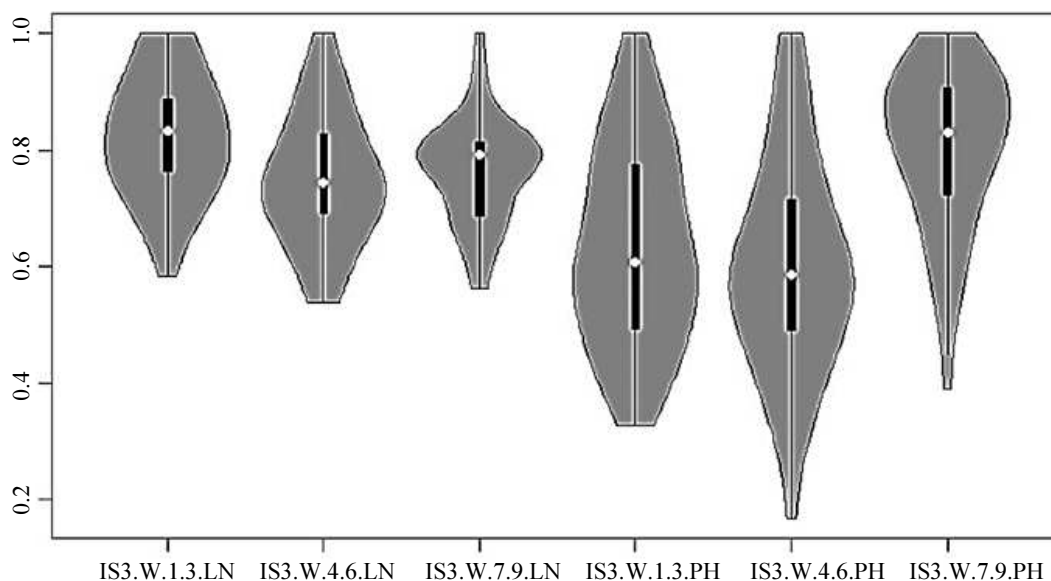
Fig. 7: Evaluation of maize plants height and leaves number growth features data dynamism (variability) in maize/cowpea intercropping plating patterns based on maize and cowpea rows alternation planting design (Intercropping System 3: IS3). i.e.: IS3.W1.3.LN acronym indicates maize Leave Number features collected in maize/cowpea Intercropping Scheme 3, during week 1-3 interval, while IS3.W1.3.PH acronym indicates maize Plants Height features collected in maize/cowpea Intercropping Scheme 3, during week 1-3 interval period.
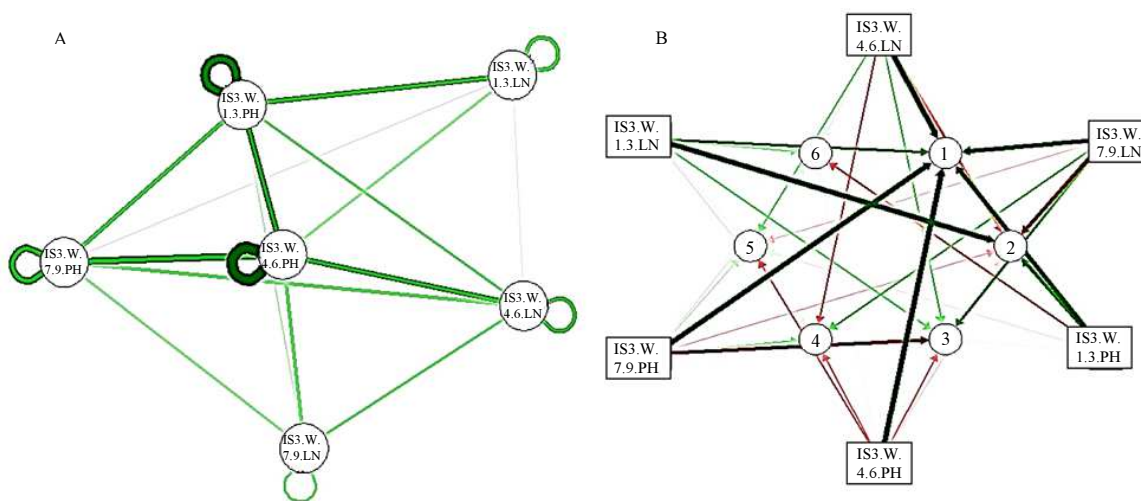

Fig. 8: Multivariate network survey by processing parallel principal component analysis (PCA) needed factors for evaluating maize plants height and leaves number growth features interactions in maize/cowpea row intercropping schemes.

Table 4: Fisher test (Degree of Freedom = 51) to compare two variances assessing cereal growth process from intercropping scheme based on maize/cowpea alternation rows (IS3 intercropping system).

	Maize/cowpea intercropping system: Maize Plant Height features for week interval 1-3 (IS3.W.1.3.PH)				Maize/cowpea intercropping system Maize Plant Height features for week interval 4-6 (IS3.W.4.6.PH)			
	IS3.W.1.3.LN	IS3.W.4.6.LN	IS3.W.7.9.LN	IS3.W.7.9.PH	IS.3.W.1.3.LN	IS.3.W.4.6.LN	IS3.W.7.9.LN	IS.3.W.7.9.PH
F	2.51	2.27	3.71	1.52	2.87	2.5	4.23	1.73
p	0.001^{***}	0.004^{**}	0.000^{***}	0.142^{NS}	0.000^{***}	0.000^{***}	0.000^{***}	0.05^{*}
95% Confidence Interval	1.44 - 4.38	1.3 - 3.95	2.13 - 6.47	0.87 -2.64	1.64 - 5.00	1.49-4.51	2.43-7.38	0.99-3.01

$^{***}p<0.005$ and NS $p>0.05$. i.e.: IS3.W.1.3.LN is for Intercropping System 3 (see material and method) with regard maize Leaves Number growth data features collected during Week 1,2 and3.

So, findings suggested both component 1 and 2 as useful factors in predicting relationship network between processed maize growth features in IS3 experimental site. Indeed, component 1 exhibited a high concordance between maize plant height and maize leaves number features for week intervals 4-6 and 7-9 as opposed to week interval 1-3 (Fig. 8B). Interestingly, our PCA network survey suggested components 1 and 2 as better factors in explaining maize plant height (PH) and maize leave number (LN) parameters respectively for week interval 1-3 (Fig. 8B). This result confirmed previous observed difference (Fig 5) in maize plants growing process (in term of plant height and leave number dynamism) between (i) week interval 1-3 and both (ii) week intervals 4-6 and 7-9 suggested in parcels with alternation of maize and cowpea rows. Also, component 3 relatively provide an interaction relationship between maize plant height and leaves number features during week interval 7-9 characterized by a modest variability (Fig. 8B and Fig 7). Taking together, the present findings proposed previous discriminated component 1 and 2 as main factors explaining maize cereal growing process in presently considered IS3 intercropping site.

Discussion

Mixed culture or intercropping of legumes and cereals is an old practice in tropical agriculture that dates back to ancient civilization (Francis and Stern, 1987). The main objective of intercropping has been to maximize use of resources such as space, light and nutrients (Willey, 1990; Morris and Garrity 1993; Li *et al.*, 2003), as well as to improve crop quality and quantity (Izaurralde *et al.*, 1990; Mpairwe *et al.*, 2002). Here we essayed several maize/cowpea mixed culture schemes patterns, aiming to improve maize plants growth processes in a low fertile arid ground in northern of Cote d'Ivoire. Then, results of our investigation based exclusively on a multivariate statistical analysis. Findings by a clustering survey based on Pearson correlation test suggested maize/cowpea intercropping design patterns preeminence regardless processed maize plants growth features (leaves number and plant high) as well as data collection periods. So, present findings suspected the preeminence of maize/cowpea intercropping scheme aptitude (intercropping design) in improving maize plants development (growth process) in arid ground in northern of Cote d'Ivoire. Michael *et al.* (2017) reported intercropping systems in poorly fertile fields as recording greater land equivalent ratio compared with fertile fields. This suggests that intercropping is more beneficial in less fertile fields and in more marginal environments. Also, Pearson clustering survey revealed a high synergy between maize plants growing process and leaf germination in maize/cowpea

mixture culture systems as opposed to crop with sole maize. Several studies supported that intercrop practices can enhance weed suppression and crop production, compared with sole crops (Davis and Liebman, 2003; Saucke and Ackermann, 2006). In the same tendency, numerous surveys exhibited maize as dominant species in cereal/legume mixture culture indicating the competitiveness of maize as opposed to cowpea in mix planting pattern (Dhima *et al.*, 2007; Yilmaz *et al.*, 2007). These evidences could justify the high variability observed in both maize/cowpea intercropping schemes (IS2 and IS3) as opposed to cropping system including maize sole, in evaluating maize plants growth features. Spatial intercropping patterns have been studied in Northern Ghana (Agyare *et al.*, 2006; Konlan *et al.*, 2013) and Nigeria (Ajeigbe *et al.*, 2010) mainly under controlled conditions. All these studies assessed the performance of different distinct alternate row intercropping patterns of maize and legumes. Rusinamhodzi *et al.* (2012) evoked greater land equivalent ratio when the intercrops were planted in the same row rather than in distinct rows in Central Mozambique. In addition, Konlan *et al.* (2013) showed intercrop advantages over sole crops that declined as the width of adjacent strips of each crop was increased. Next, performed multivariate statistical survey shown high performances of intercropping practices in improving maize plants growth dynamism. Indeed, distribution function with regard maize plant height and leaves number parameters suggested parcels with alternation of maize and cowpea rows (IS3 intercropping system) as enhancing and accelerating maize plant growing process as opposed to parcel including maize plants monoculture (IS1 intercropping system) as well as to parcels with alternation of maize and cowpea plots on the same row (IS2 intercropping system). This results were also confirmed by fitting curve analysis (Sandra, 1994; William, 1984) establishing a mathematical relationship between previous mentioned intercropping designs and/or systems planting patterns. Therefore, maize/cowpea intercropping in different patterns and mix-proportions as well as in culture disposition, may affect plants development as well as grain yield because of competition between crops compared to sole cropping (Yilmas *et al.*, 2007; Takim, 2012). In addition, the analysis of variance (ANOVA) supported significant difference between the two maize/cowpea intercropping planting practices (IS2 and IS3 intercropping schemes) by assessing maize plant height and leaves number growth features ($p<0.0001$; $p<0.001$ respectively). This result indicated the competitiveness of maize in mix-proportions and planting patterns (Zhang and Li, 2003). Further, ANOVA survey global test confirmed the good performance of maize/cowpea intercropping system including parcels with alternation of maize and cowpea rows as opposed to IS2 intercropping scheme including maize and cowpea plot alternation on the same rows and as well IS1 cropping system (maize

monoculture practice), in promoting maize plants growth process (p = 0.00). Then, present survey promoted maize and cowpea row alternation mixture culture experimental design as a satisfactory approach for accelerating maize plants growth and as well productivity (Zhang and Li, 2003). Taking together, findings advised that competitive and facilitative interactions in intercropping systems enhances crop development and as well productivity by arranging efficient nutrient use (Zang and Li, 2003; Ofuso-Amin and Limbani, 2007). Next, the present analysis highlighted processed maize growth features dynamism in maize/cowpea intercropping systems with alternation of maize and cowpea rows. Indeed, findings exhibited significant (p<0.05) high correlation coefficient (R^2 = 0.8) between maize plants height and leaves number features during plants early growing period (first three week). However, this correlation coefficient strongly decreased after the seventh month (R^2; from 0.8 to 0.46), suggesting early development instant as a favorable period for maize cereal plants leaf germination. Interestingly, performed parallel principal component survey discriminated early growth period by evaluating maize height features, as satisfactory parameters explaining maize plants development and/or growth speediness in the intercropping systems referred to maize and cowpea rows alternation mix culture pattern (intercropping system IS3) as opposite to the other intercropping and/or monoculture arrangements. Considering as a whole, maize/cowpea mixed culture based on maize and cowpea rows alternation appeared to improve maize plants competiveness in their early development stage period. Principal component network analysis confirmed maize plants early (1-3 week interval) and middle (4-7 week interval) growing periods as satisfactory parameters explaining (more than 95% of cumulative variance) presently processed maize plants growth dynamism. Also, we believe that demand for labor saving technology could become a necessary condition for further agricultural intensification in southern countries at least in areas with better market access and higher opportunity costs of rural labor (Nin-Pratt and McBride, 2014). Thus, it is possible that the lack of labor-saving technology and/or mechanization limits the potential returns to certain types of land saving technology such as improved seeds and application of fertilizers and pesticides, unless such labor constraints can be overcome through mechanization (Nin-Pratt and McBride, 2014; Ndlovu *et al.*, 2014). Presently processed intercropping systems (IS2 and IS3 inter-cropping schemes) can be easily integrated to above mentioned labor-saving technology with the purpose to improve agricultural land productivity and as well crops growth and yield. Although we provided detailed statistical survey for explaining maize growth dynamism in a cereal/legume intercropping systems, we believe that next investigation by processing either maize yield and growth features with the purpose to link cereal/legume intercropping

design patterns with maize growth and yield performance in agricultural practices is essential.

Conclusion

Findings clearly shown high performance with regard maize/cowpea (cereal/legume) intercropping planting pattern in promoting early maize growth speediness as well as suggested the good propensity of maize/cowpea intercropping design pattern based on maize and cowpea row alternation in strongly improving maize cereal growth dynamism. Finally the present bio-statistical approach provided a pattern confirming the narrow relationship between experimental design in agronomic research and statistical data analysis and as well statistical model.

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Author's Contributions

Dago D. Noel, Ph.D: Organized data collection; data pre-processing and/or pre-treatment as well as analysis; prepare the figures and wrote the manuscript.

Dr Tuo Yalamoussa: Set up the experimental device and read and approved final version of the paper.

Dr Niamien Coffi JM: Read and approved final version of the paper**.**

Mr Dagnogo Dramane and Mr Kablan Gnoan A.J.: Collected the data and participated to the data analysis.

All Authors read the paper and approve final version.

Conflict of Interest

The authors have not declared any conflict of interests.

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