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Agromorphological evaluation within a collection of local tomato (*Solanum lycopersicum* L.) populations collected in Burkina Faso and Mali

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Tomato is a vegetable of great economic importance in Burkina Faso. This study evaluated agromorphological diversity within 40 tomato accessions from Burkina Faso and Mali. Trials were conducted during 2015 growing season and IPGRI descriptors were considered in collecting data on field as well as in laboratory. Results revealed the collection to be interestingly diversified. All studied characters presented several modalities, with heterogeneous one predominant. Leaf type, external color of both immature and mature fruit was the most variables showing 5 homogeneous modalities in each case. *Peruvianum* leaf type was predominant (17.5%) followed by standard type (5%) while red was the main fruit color at maturity in 25% of accessions. Rare interesting traits, that is, *Hirsutum*, dwarf, potato leaf types, and yellow and orange mature fruit color could be highlighted by detailed investigation on heterogeneous accessions. PCA clustered accessions in 4 groups, with G1 (cherry fruit) and G3 (large and flattened fruit) the most distinctive ones. The strongest positive correlations were observed between number of inflorescences per branch and average number of fruits per plant. This entire variability could be used in tomato breeding program, especially to enhance the β-carotene content in Burkina Faso tomato local varieties.

Key words: Tomato, accessions, variability, Burkina Faso, Mali.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a multipurpose vegetable widely used for human feeding. Mature fruits of tomato are eaten fresh and used industrially to manufacture a large number of processed products such as dough, powder, ketchup, sauce, soup, etc. Nowadays, some whole fruits can be found sold in conserve while

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immature green fruits are used for marinades, canned foods and are eaten after cooking. Tomatoes are an important source of mineral salts, vitamins, β-carotene and especially lycopene, a powerful antioxidant that fights certain cancers (Giovannucci et al., 1995).

Burkina Faso is an agricultural and pastoral vocation country where agriculture occupies an important economic place and is practiced by more than 80% of households, mostly in rural area. Agriculture is the main source of income for majority of population and contributed on average 15.36% of Gross Domestic Product in 2017 (INSD/MEFD, 2017). Market gardening is the first of production sector, which creates many jobs in rural areas during the dry season and generates substantial income for young people and women (MAHRH, 2007).

Today, in an environment affected by climate change and globalization, Burkina Faso's major challenge is to ensure food and nutrition security for a rapidly growing population by 3.42% annual average (INSD/MEFD, 2017) while sustainably preserving natural resources. To meet this challenge, a special emphasis is placed on vegetable production, which has become an important sector via job creation and fighting against poverty.

In Burkina Faso, tomatoes are the second market garden crop produced after onions. Area planted tomatoes is superior to 23,000 ha, representing nearly one-quarter (24.75%) of total vegetable acreage while production is about 200500 tons, that is, just over 25% of total national market garden production (MAAH, 2017). This infatuation for vegetable production, as well as for most cash crops, led to an expansion and massive use of modern varieties to the detriment of traditional ones, which are disappearing. In Burkina Faso, global adoption rate of improved seeds in market gardening is 78% while this rate for tomato raises to 84% (MAAH, 2017). It is known that modern varieties occasioned productivity increases with some economic benefit for producers. However, their massive adoptions rise up risks of genetic erosion to local material which, nevertheless is well suited to local production conditions and carrying exploitable gene pools.

Success in plant breeding depends on availability of genetic variability within working material to enhance/ breed cultivated varieties that is why identification of variability among accessions is essential to maintenance and use of genetic resources. Agro morphological characterizations are a quick and inexpensive way to know a starting new material (Mwirigi et al., 2009).

Therefore, germplasm collecting mission to identify and gather local tomato accessions in Burkina Faso and some districts in Mali were accurately planned. From these exploration and collecting activities, a seed collection of 40 tomato local varieties was assembled.

This study is a preliminary characterization of the collection, consisting of intra-accession variation assessment. The global objective is to study the agro-morphological diversity within the collection, with specific aims to (i) study through morphological variables, the phenotypic diversity within each accession; (ii) to study the broad variability and heritability of certain agronomic variables within tomato accessions; (iii) to study the relationships among accessions.

MATERIALS AND METHODS

Study site

The experiment was conducted in 2015 at Farako-Bâ research station. This station is located in the western part of Burkina Faso, between isohyets 800 and 1200 mm, at 405 m of altitude, 4°20'W of longitude and 11°06'N of latitude. Soils are lexisols with low clay and organic matter content, with a notable deficiency in nitrogen and phosphorus (Bado, 2002). Climate is South Sudanian type with a cumulative rainfall of 1048.8 mm in 68 rainy days in 2015.

Plant

The whole collection was considered in this study, that is, 40 local tomato accessions. Most of the accessions precisely 27 were collected in different districts and villages in Burkina Faso. The remainders were assembled from some villages in Mali near the borderline Mali-Burkina Faso, in the western part of Burkina Faso. More details on characteristics of the accessions are shown in Table 1.

Experimental design and field experiment

From each accession, 150 to 200 seeds were first sown and nursed during 21 days to produce healthy and vigorous plants to be transplanted in open field.

The experimental design in open field was arranged in a randomized complete block design with four replications separated from each other by a 2-m wide alley. Each elementary plot, that is, useful plot comprised three transplanting rows of 5 m long. Distances row-to-row and plant-to-plant were 1 and 0.5 m, respectively.

As regard to tomato production technical guidelines (Rouamba et al., 2013), transplanting plot was previously ploughed using a mini-tractor followed by manual harrowing and leveling. Organic fertilization with organic compost was applied at 20 t/ha. Transplanting was done in the afternoon, in order to limit heat stress to plants and promote their good and fast recovery. Mineral fertilization consisted of 300 kg/ha NPKB (14-23-14-6) applied two times at 150 kg/ha two weeks after transplanting and at blomming. For plant protection, Mancozeb 80 WG at 2 kg/ha against fungi and Lambdacyhalothrin + Acetamiprid 215 EC, at a 1 L/ha was applied to control caterpillars, aphids and white flies. Frequency of insecticides spraying was the function of the level of infestation. Manual weeding and plant tutoring were conducted on demand throughout the experiment time.

Data collection

Collected data were of two types, that is, qualitative ones, recorded on vegetative and fruit characteristics and quantitative ones as agronomic variables were concerned.

Qualitative observations were recorded on the whole plants in

Table 1. List of the studied accessions of tomato and their collection sites.

Code	Country	Province	Department	Village
12T2	Burkina Faso	Houet	Karangasso S	Toronson
12T3	Burkina Faso	Houet	KarangassoVigué	Saaré
13T1	Burkina Faso	Ioba	Dano	Bonembar
15T1	Burkina Faso	Kénédougou	Kangala	Mahon
15T5	Burkina Faso	Kénédougou	Orodara	Tin
15T6	Burkina Faso	Kénédougou	Orodara	Tin
1T1	Burkina Faso	Balé	Pâ	Boro
21T1	Burkina Faso	Kossi	Nouna	Babigolo
23T1	Burkina Faso	Loroum	Titao	BoumaYiri
25T2	Burkina Faso	Nahouri	Pô	Tambolo
25T3	Burkina Faso	Nahouri	Pô	Tambolo
27T2	Burkina Faso	Nayala	Kougny	Kougny
27T3	Burkina Faso	Nayala	Kougny	Niaré
27T4	Burkina Faso	Nayala	Kougny	Tiouma
2T4	Burkina Faso	Bam	Kongoussi	Kongoussi
30T1	Burkina Faso	Oudalan	Gorom-Gorom	Gorom-Gorom
31T3	Burkina Faso	Passoré	Goumpounssou	Minsnoogué
32T1	Burkina Faso	Poni	Boussera	Nonkinena
34T1	Burkina Faso	Sanmatenga	Kaya	Zannogo
34T2	Burkina Faso	Sanmatenga	Kaya	Zannogo
38T1	Burkina Faso	Sourou	Lanfièra	Lanfièra
3T1	Burkina Faso	Banwa	Kouka	Molli
3T3	Burkina Faso	Banwa	Kouka	Molli
4T1	Burkina Faso	Bazèga	Kombissiri	Kombissiri, sect 5
4T2	Burkina Faso	Bazèga	Kombissiri	Saberaogo
4T3	Burkina Faso	Bazèga	Doulgou	Gana
5T1	Burkina Faso	Bougouriba	Diébougou	Bapla-Birifore
MlT1	Mali	Bougouni	N'Tjila	Bougouni
MlT10	Mali	Bamako	Bamako	EIR
MlT11	Mali	Bamako	Bamako	EIR
MlT12	Mali	Bamako	Bamako	EIR
MlT13	Mali	Bamako	Bamako	EIR
MlT2	Mali	Bougouni	Bougouni	Djambala
MlT3	Mali	Bougouni	Bougouni	Toula
MlT4	Mali	Koutiala	Kèlèni	Ziéna

Table 1. Contd

MIT5	Mali	Ségou	Siguidolo-Bamana	Konobougou
MIT6	Mali	Kati	Dougoulakoro	Baguineda
MIT7	Mali			
MIT8	Mali	Bamako	Bamako	EIR
MIT9	Mali			

each elementary plot. Almost all data were recorded after the second harvest taking reference to IPGRI descriptor (IPGRI, 1996). To characterize the vegetative part, visual observations were done on all 30 plants per replication of each elementary plot for growing type, plant size, foliage density and leaf type. Then, a grade corresponding to the visual observation for the whole 30 plants per replication was recorded. About fruit characteristics, observations were conducted on 10 immature fruits randomly chosen in each replication (40 fruits in total) to record exterior fruit color. In laboratory, data were also collected on fruit at maturity, chosen in the same number and same approach as immature ones, to record exterior fruit color at maturity, shoulder shape, cross-sectional shape, and firmness as recommended by IPGRI (1996). To make data more comprehensible and better analyzed, the presence of a character (modality) was considered homogeneous if all the plants or fruit populations investigated on one accession showed the same grade for that character. If several characters (modalities) are observed in the population of the same accession, a so-called heterogeneous additional modality was added for characterization of the accession (Bourgou et al., 2014). Thereafter, for some variables of interest, that is, leaf type, exterior immature and mature fruit color, heterogeneous modalities were more investigated to highlight proportion of rare modality (character never expressed in homogeneous status in an accession) within the heterogeneous population. To finish this, particular accessions expressing these "rare" modalities were pointed out (Table 3).

Quantitative data were recorded in field on plants constituting central row of each elementary plot, and in laboratory on fruits after harvesting. Variables recorded on field were the blooming period (Dflow), that is, the date by which 50% of the plants in elementary plot produced at least one flower; the number of inflorescence per branch (NFB), the number of fruit per plant (NF) and the yield in mature fruits (YLD). The yield was calculated using the following formula:

$$\mathbf{YLD\ (t/ha) = MFW\ (g)/100\ x\ S\ (m^2)},$$

where FW = marketable fruits weight weighted in kg on field using a manual scale; S = acreage of harvested useful plot.

Quantitative fruit variables were obtained from laboratory as the average value of ten (10) randomly selected fruits. Fruit length (FL in mm) and fruit diameter (FD, in mm) were measured using calipers. Fruit weight (FW), in grams, was measured in laboratory using an electronic scale with error margin ± 0.1 g.

Data analysis

All collected data were typed in Excel 2013 and the software was used to calculate, via qualitative data, frequencies (%) of each modality for each variable. For some variables of interest (exterior immature and mature fruit color), the heterogeneous modality was more detailed to point out share of each heterogeneous part. Quantitative data were subject to both descriptive statistics analysis and Principal Component Analysis (PCA) using Rx 64.3.2.1 software. These quantitative data have also been analyzed through an analysis of variance (ANOVA).

All different analysis on quantitative variables aimed at describing intra-accession variability within the collection and revealing clustering pattern in groups of similar or dissimilar accessions.

RESULTS

Variability analysis of qualitative characteristics

Qualitative observations within accessions highlighted a variability of characters, as evidenced by the diversity of modalities for each character (Tables 2 and 3). Both in terms of vegetative and fruit characteristics, each character has presented several modalities including the heterogeneous one.

As all studied characters were concerned, heterogeneous modality was dominant. In vegetative, heterogeneous modality represented 77.5% in leaf type, 75% in foliage density, 65% in plant size and 45% in growth type. The remainders, that is, homogeneous modalities within the accessions were of low to very low frequencies. For leaf type trait, 17.5% accessions were homogeneous in *Peruvianum* type and 5% in Standard type. For growth type, it was observed that 35% are determined type, 17.5% of indeterminate type and only 2.5% of semi determined type. As plant size character, both small and large modalities represented 10% each against 15% for intermediate modality. The same trends have been observed on foliage density with 5% frequency for spare and dense modalities versus 15% for intermediate modality.

Tomato is grown for its fruits and in this study, more than half of the qualitative characters were observed on this organ. In a set of variables, heterogeneous modality was found as dominant as in the case of vegetative. Therefore, heterogeneous modality represented 87.5% in fruit firmness, 82.5% in exterior immature fruit color, 72.5% in exterior mature fruit color, 70% in shoulder shape, and finally 55% fruit cross-sectional shape (Table 2). Regarding to fruit qualitative characteristic (Table 2), related traits exhibited three modalities from exterior immature fruit color trait, that is, greenish-white and dark green with 2.5% frequency each, green modality at 12.5%. About to exterior mature fruit color, one-quarter

Table 2. Modalities and frequencies highlighted for analyzed characters in 40 tomato accessions collected in Burkina Faso and Mali.

Observed part of the plant	Analyzed characters	Modalities	Frequencies (%)
Vegetative	Plant growth type	Determinate	35
		Semi-determinate	2.5
		Indeterminate	17.5
		Heterogeneous	45
	Plant size	Small	10
		Intermediate	15
		Large	10
		Heterogeneous	65
	Foliage density	Sparse	5
		Intermediaire	15
		Dense	5
		Heterogeneous	75
	Leaf type	Dwarf	0
		Hirsutum	0
		Potato leaf type	0
		Peruvianum	17.5
		Standard	5
		Heterogeneous	77.5
Fruits	Exterior color of immature fruit	Greenish-white	2.5
		Light green	0
		Green	12.5
		Dark green	2.5
		Very dark green	0
		Heterogeneous	82.5
	Exterior color of mature fruit	Yellow	0
		Orange	0
		Pink	0
		Red	25
		Dark red	2.5
		Heterogeneous	72.5
	Fruit shoulder shape	Slightly depressed	20
		Moderately depressed	5
		Strongly depressed	5
		Heterogeneous	70
	Fruit cross-sectional shape	Round	42.5
		Angular	0
		Irregular	2.5
		Heterogeneous	55
	Fruit firmness	Soft	5
		Intermediaire	0
		Firm	7.5
		Heterogeneous	87.5

Table 3. Rare modalities and frequencies in heterogeneous accessions of tomato from Burkina Faso and Mali.

"Rare" modalities	Frequencies inside the heterogeneous population	Accessions expressing the "rare" modality
Dwarf leaf type	3.23	25T2; 30T1; 4T3; MlT7
Potato leaf type	16.13	34T1; MlT2; 1T1; 23T1; 3T1; 4T2; 25T2; 31T3; 34T2; MlT1; MlT10; MlT9
Hirsutum leaf type	4.02	1T6; 27T3; MlT12; 15T4
Light green	10.77	13T1; MlT5; 15T1; 8T1
Very dark green	10.69	2T4; 31T3; 34T1; MlT1; 23T1; 15T4; 25T3; MlT7
Yellow	1.94	MlT5; 1T1; 15T1
Orange	3.87	15T6; 25T3; 4T2; 18T3; MlT5; 4T3
Pink	23.87	27T4; 5T1; MlT4

Table 4. Descriptive statistics, coefficient of variation and broad sense heritability of quantitative variables in 40 tomato accessions collected in Burkina Faso and Mali.

Variable	FD (mm)	FL (mm)	FW (g)	Dflow (JAR)	NFB	NF	YLD (t/ha)
Minimum	17.77	20.63	9.00	25.00	2.40	20.00	2.60
Maximum	94.62	74.76	206.90	44.00	7.00	2838.00	53.30
Median	51.11	41.79	70.90	35.00	3.50	112.50	10.15
Mean	51.50	44.11	71.97	34.71	3.58	217.24	11.50
E.T (n-1)	11.46	11.90	32.78	3.65	0.74	341.88	6.02
C.V (%)	26.93	26.93	45.49	10.49	20.68	156.88	52.19

FD (mm) = Fruit diameter; FL = fruit length (mm); FW (g) = fruit weight; Dflow (JAR) = blooming period; NFB = number of inflorescence per branch; NF = number of fruit per plant; YLD (t/ha) = yield.

(25%) of accessions was red colored, while only one accession (2.5%) was dark red colored. For fruit shoulder shape, moderately depressed and strongly depressed types were homogeneous for 5% of accessions while slightly depressed type was present in 20% of accessions. For fruit cross-sectional shape, 42.5% of accessions exhibited round modality and 2.5% (only one accession) was irregular modality. Data on fruit firmness revealed 5% accessions were soft modality while 7.5% were firm modality.

From detailed investigations on intra-accessions qualitative variables analysis, it appeared that some modalities absent in homogeneous status could be found in small proportions within heterogeneous class. These so-called rare frequency modalities were calculated taking into account whole heterogeneous population and are shown in Table 3. It is the case of dwarf, potato and *hirsutum* leaf type present in 3.23, 16.13 and 4.02% proportions, respectively within vegetative parameter. It is also the case of light-green (10.77%) and very dark green (10.69%) modalities from exterior immature fruit color while from exterior mature fruit color parameter, Yellow (1.94%), Orange (3.87%) and Pink (23.87%) modalities were pointed out.

Quantitative characteristics analysis

Table 4 presents the results of descriptive statistics on observed quantitative variables. Results showed that the greatest magnitude of variation was observed in the number of fruits per plant in the range of 20 to 2838 as minimum and maximum, respectively. Large differences in minimum and maximum were in yield variables (from 2.60 to 52.19 t/ha), in fruit weight (from 9 to 206.90 mg), in fruit height (from 20.63 to 74.76 mm) and to a lesser extent in fruit diameter (from 17.77 to 94.62 mm). In contrast, number of inflorescence per branch and to a lesser extent the blooming period varied in little magnitude, between 2.4 and 7 and between 25 and 44 days after transplanting, respectively.

Analysis of variance for the quantitative traits showed a large and significant variation between the accessions (data not showed). Coefficients of Variation (CV, Table 4) deduced from descriptive statistics are in similar trends with analyzed parameters, widely fluctuating from one variable to another. Coefficients of Variation for Dflow and NFB were below 25%, but CV appeared excessively high for some other variables, namely NF (CV= 156.88), YLD (CV= 52.19) and FW (CV = 45.49).

Accessions grouping analysis using Principal Component Analysis (PCA)

First two main components (CP1 and CP2) were used to describe inter-accessions diversity within the collection. Both CP1 and CP2 were explaining 72.61% of this

Table 5. Summary of PCA, cosinus square, values and contributions of variables to PCA axes in 40 tomato accessions collected in Burkina Faso and Mali.

Variable	F1		F2		F3	
	Cosinus square	Contribution (%)	Cosinus square	Contribution (%)	Cosinus square	Contribution (%)
FD	0.509	14.085	0.301	20.555	0,030	5,027
FL	0.350	9.677	0.330	22.534	0,141	23,846
FW	0.745	20.605	0.071	4.848	0,051	8,569
Dflow	0.129	3.568	0.550	37.525	0,283	47,756
NFB	0.679	18.767	0.019	1.299	0,068	11,548
NF	0.797	22.026	0.023	1.561	0,000	0,061
YLD	0.408	11.272	0.171	11.677	0,019	3,194
Eigenvalue	3.617		1.466		0.592	
Variance (%)	51.665		20.942		8.456	

FD (mm) = Fruit diameter; FL = fruit length (mm); FW (g) = fruit weight; Dflow (JAR) = blooming period; NFB = number of inflorescence per branch; NF = number of fruit per plant; YLD (t/ha) = yield.

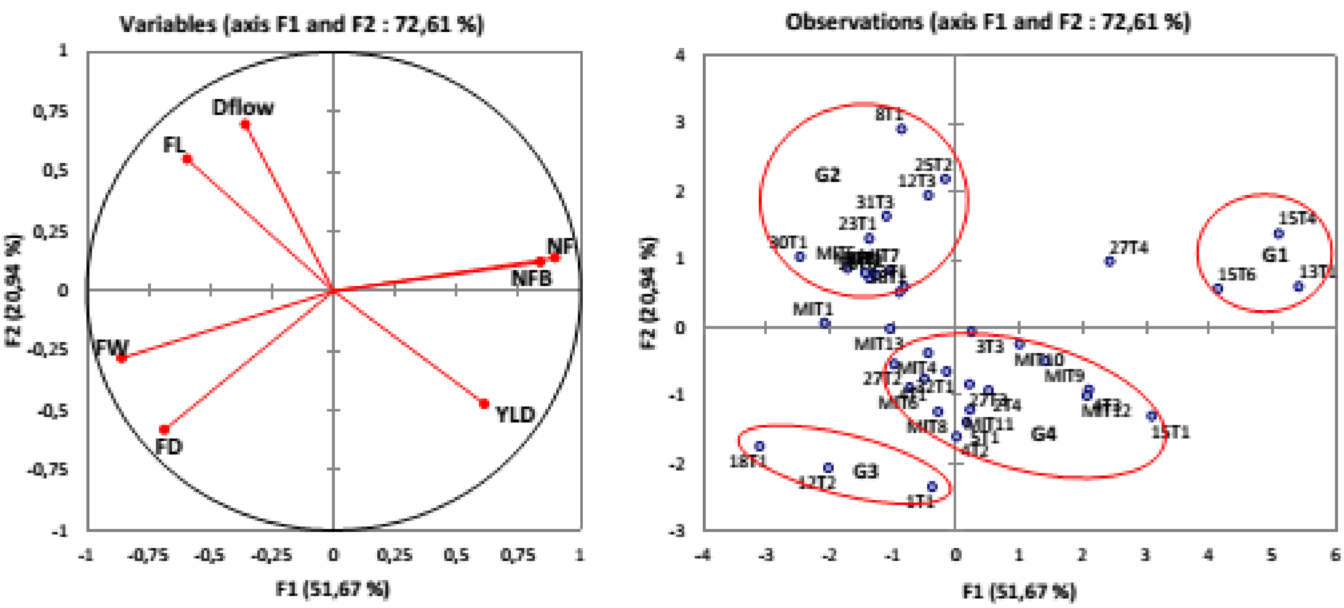

Figure 1. Contribution of variables to Axes 1 and 2 formation and structure of tomato accessions in the plan defined by Axes 1 and 2 of the PCA.

diversity (Table 5). CP1 (axis 1) alone explained more than 51% of variation. Fruit number per plant (NF) variable, by its strongest contribution to axis 1 (22.03%), was best explainer of CP1 followed by fruit weight (20.61%) and the number of inflorescence per branch (18.77%). These three variables are known as tomato yield components, CP1 axis can therefore be designated yield axis.

Second axis (CP2) described 20.94% of collection variability. Associated variables, in order of importance by their contributions to constitute the axis, are blooming time (37.53%), fruit length (22.53%) and fruit diameter (20.56%). Through CP2, it is both plant cycle and fruit size which are explained as in crop production, cycle length is proportional to yield components then to yield itself.

Representation of accessions in the plane defined by two main components CP1 and CP2 (Figure 1) shows a fairly structured distribution of accessions. Taking reference to qualitative variables discussed earlier, 4 groups can be highlighted (Figure 1).

The first group (G1) composed of three accessions, namely 13T1, 15T4 and 15T6 which are sharing common characteristics, that is, a high number of inflorescences per branch (4.8) and a high number of fruit per plant (more than 700). This group contains accessions producing small fruit or cherry type fruit.

Individuals composing the second group (G2) were correlated with the CP2 axis whose characteristics are about blooming time and fruit height. This group contains long cycle individuals producing elongated fruits. The most notable accessions are 8T1, 31T3 and 12T3 which exhibit blooming time equal or up to 40 days after transplanting.

The third group (G3) was easy to highlight as accessions constituting the group were sharing common fruit size characteristics, that is, FD>60 mm and FW>100 g. It contains three accessions namely 12T2, and the two lowest fruit yielding accessions 18T1 (4.95 t/ha) and 1T1 (23.25 t/ha).

The fourth group (G4) composed of unclustered accessions to one of well-defined groups G1, G2 or G3 in this study using qualitative traits. Accessions in this group are sharing some similar characteristics to both group 1, 2 and 3 accessions.

The correlation matrix between different quantitative variables (Table 5) makes it possible to evaluate the links and to inform the breeder about character(s) in positive or antagonistic connection to be taken into account in a selection program.

DISCUSSION

Interesting diversity revealed within the collection

Taking into account plurimodality of studied characters and existence of a dominant modality known as heterogeneous within which many rare characters have been revealed, this collection can be considered to represent a wide range of diversity of tomato (Frankel et al., 1995).

For some traits such as growth type, foliage density, shoulder shape and fruit firmness as well as cross-sectional shape of the fruit, the present results showed similar patterns to those from previous studies of tomato collections. For growth type, reported modality types varied from two (Terzopoulos and Bebeli, 2010) to four (Bhattarai et al., 2018). Three different modalities have been reported by Sacco et al. (2015) as in the present study. These previous authors have also been highlighted, in studying their respective collections, the three common modalities of foliage density character, namely sparse, intermediate and dense, in different proportions similar to the present study results. With regard to fruit shoulder shape, our collection is rich of the three common modalities known for the character (flat, moderately depressed and strongly depressed) as also found by Salim et al. (in press). Bhattarai et al. (2018) reported more modalities from their collection, precisely six, but they are found to be just variants of the three known ones.

Varietal diversity in tomato is more appreciable through qualitative characteristics related to leaves and fruits (Natarajan et al., 1994; Patel et al., 2001; Aravind Kumar et al., 2003). As leaf type is concerned, Salim et al. (in press) highlighted in their study three leaf types as dwarf, standard, and potato leaf type. Bhattarai et al. (2018) also reported three types of leaves namely standard, *peruvianum* and potato leaf type; the present collection is then more diversified compared to those of these two authors, as it exhibits five modalities including the *hirsutum* type not mentioned by them.

As immature fruits color is concerned, the present results are similar to those of Vishwanath et al. (2014) and Salim et al. (in press) who reported from their studies four modalities, similar to the present study (greenish-white, light green, green and dark green). At maturity, red color of fruit appears to be predominant as reported by several authors (Sondo, 2017; Kenneth, 2016; Sacco et al., 2015; Vishwanath et al., 2014; Terzopoulos and Bebeli, 2010). Salim et al. (in press) found their collection to exhibit five color modalities at maturity (red, pink, light red, dark red and yellow); in this study also, mature fruit yellow, orange and pink colors were highlighted, even if in low proportions. However, our collection appears more diversify compared to those of Bhattarai et al. (2018), Sacco et al. (2015), and Terzopoulos and Bebeli (2010) at taking regard to exterior fruit color at maturity.

For quantitative traits, the level of coefficients of variation (Table 4) indicates a high genotypic variability among accessions, and therefore a potential to improve most of these traits by selection (Dar and Sharma, 2011; Rani and Anitha, 2011; Kumar et al., 2014). Also, inter-accessions variability demonstrated for all quantitative parameters by ANOVA (Pr<0.0001, data not showed), is a source of genotypic variability within a collection available to the breeder (Agong et al., 2001; Bationo-Kando et al., 2015).

A potential for improvement using the collection

Variability is a characteristic of local populations that offers the possibility to be utilized for genetic improvement. In the collection, variability is present in the heterogeneous group and selection of accessions will reveal interesting traits, such as orange and yellow exterior fruits color at maturity for the creation and improvement of tomato varieties with high β-carotene in a breeding program (Sondo, 2017).

In traditional or semi-intensive farming, common in our country production context, indeterminate tomato genotypes (tall plant, high foliage density and scalar ripening) are found more suitable, and via our collection, this kind of material exists and can be valued directly or after more improvement (Lerner, 2009). This is the case of accessions 13T1, 15T4, 15T6, 27T2 and 27T3. On the other hand, always in our collection, genotypes with determined growth habit could be useful in developing tomato varieties intended to mechanized harvesting

Table 6. Pearson correlation matrix between quantitative variables in 40 tomato accessions collected in Burkina Faso and Mali.

Variable	FL	FD	FW	NFB	Dflow	NF	YLD
FL	1						
FD	0.120	1					
FW	0.295	**0.747**	1				
NFB	**-0.438**	**-0.517**	**-0.673**	1			
Dflow	**0.451**	-0.071	0.204	-0.131	1		
NF	**-0.419**	**-0.669**	**-0.741**	**0.730**	-0.226	1	
YLD	**-0.487**	-0.241	**-0.411**	**0.388**	**-0.373**	**0.450**	1

FL = Fruit length (mm); FD (mm) = fruit diameter; FW (g) = fruit weight; NFB = number of inflorescence per branch; Dflow (JAR) = blooming period; NF = number of fruit per plant; YLD (t/ha) = yield. Bold values are significantly different from 0 at a level of significance alpha of 0.05.

(Kallo, 1991); but that is not yet actual in our country.

As foliage density is concerned in tomato breeding, it is a result of enhancement with the aim to protect fruits from direct sunlight, bird attacks and finally, for facilitating harvesting process (case of sparse foliage). Moreover, it is a high valuable trait as genotypes with dense foliage were known to exhibit more tolerance/resistance to abiotic (hot and humid conditions) and biotic (bacterial and fungal diseases) stresses (Kallo, 1991). However, extreme cases of foliage density, that is, extremely dense foliage, or extremely sparse foliage as described in tomato descriptor (IPGRI, 1996), are not usual and difficult to find. The reason is that these kind of materials is anti-selected because it does not produce enough energy to compete (sparse case), or is using too much of its produced energy to keep its dense foliage (dense case), making these materials less fit to compete against other genotypes (Bhattarai et al., 2018). As a resolution, tomato breeding and enhancement should more focus on intermediate foliage density in breeding genotypes to be grown in field conditions, while in controlled production conditions (no energy limiting conditions), it is wise to use varieties with high foliage density for better fruit quality.

Leaf type is an excellent indicator of phenotypic varietal diversity. As example, in seed production, it is the most commonly used variable to determining and removing undesired types in field, before flowering and fruiting; in breeding new varieties, use of different types of leaf as a phenotypic marker, would be an asset.

Fruit shoulder shape (Bhattarai et al., 2018), as well as fruit external coloration, are visual organoleptic characters highly determining in consumers choice. Tomato fruit color is a result of chlorophyll degradation during ripening process; it appears to be an outward sign of quality and a major indicator of consumer choice (Causse et al., 2001, 2002). Moreover, fruit color reveals indication on tomato biochemical composition and nutritional quality. It is known that the presence and type of pigments in plants influence color of plant organs and specially the case of tomato. Red fruit color is indicative of good lycopene content, while orange and yellow colors are indicative of β-carotenes (Ronen et al., 1999, 2000). First steps to improve these nutritive traits begin through identification of accessions expressing these desired pigments; it is revealed in our collection that at least six orange colored accessions (15T6, 25T3, 4T2, 18T3, MlT5 and 4T3, in Table 3), potential donors in β-carotene, enhance popularized varieties. In addition to fruit color, fruit firmness is also of paramount importance; both constitute critical factors in consumer choice, and even more in industrial processing purpose (Luna-Guevara et al., 2014). Fruit firmness has been shown to be related to amount of dry matter and soft fruits are less fit to handling even are quickly damaged and quality degraded during mechanized harvesting and/or transport (Kallo, 1991). According to Davies et al. (1981), fruit firmness as breeding objective will reach to fresh tomatoes, more resistant to transport and storage with long-life possibility. Accessions 12T3, 13T1 and 15T4 could appear very interesting in improvement of this character. These achievements will more benefit in local tomato production context, as vegetable production areas are far from major consumption centers and where it is usual post-harvest losses due mainly to fruit rot during transport and storage.

Pearson correlation matrix (5% threshold, Table 6) reveals interesting positive correlations between FD and FW (0.747) and NFB and NF (0.730), indicating average tomato fruit weight is strongly bounded to fruit diameter as well as number of inflorescence per branch to number of fruit per plant. Concerning FD and FW, Ullah et al. (2015) reported similar results (0.86) between these two characters. As NFB and NF are concerned, our results are in agreement with Rahman et al. (2015) but not with Ullah et al. (2015); these last authors reporting negative correlation between the same characters. However, NFB and NF are negatively correlated with fruit size parameters, that is, -0.741, -0.673, -0.669 between NF and FW, NFB and FW and NF and FD, respectively. In other words, these correlations indicate that fruits are small size when number of flowers per inflorescence and/or number of fruits per plant are high (Emami and Eivazi, 2013; Ullah et al., 2015; Rahman et al., 2015; Sondo, 2017).

Yield in tomato is a compromise within plants density, number of fruits per inflorescence and fruits weight (Zdravkovic et al., 1998). In this study, it was found out that yield to be positively correlated with number of inflorescence per branch (0.39) and number of fruit per plant (0.45); these two variables are known to be yield major components. However, yield was negatively correlated with flowering time (r = -0.373) and fruit length (r = -0.487), indicating that early maturity was detrimental to yield (Ullah et al., 2015). Moreover, fruit weight average was negatively correlated with yield (r = -0.411), denoting plants with large fruits are not necessarily better yielding, as also argued by Rahman et al. (2015). However the present results are not in agreement with Dordevic et al. (2010); according to them, genotypes with high number of fruits by plant and average fruit weigh could be best materials to improve yield. Our collection offers both materials (large and small fruits) of interest in a tomato improvement program and more specifically in development of cherry tomato variety by valuing small fruits characters.

Conclusion

Taking into account all general knowledge accumulated, this study reveals a rich diversity within our tomato collection due to high qualitative as well as quantitative characteristics variability. Traits related to plant architecture (growth type, plant size and leaf density), fruit size (length, diameter and average fruit weight), and certain agronomic parameters such as day to blooming, yield and its components were found to be more diversified and of great interest. Based on main variables structuring accessions were clustered in four agro-morphological groups.

Results from these first steeps of characterization and evaluation of local accessions of tomatoes collected in Burkina Faso and Mali, will enrich tomato program gene bank for future improvement of productivity and nutritional quality value of this vegetable in Burkina Faso.

Future work will focused on molecular evaluations, particularly in understanding of relation between fruit nutritional and organoleptic qualities to resistance against certain biotic insects (bacterial wilt, pest) and abiotic stresses such as (hot conditions) of production, since they may be of interest to breeders and tomato growers. In the meantime, it is urgent to take appropriate measures to safeguard this germplasm, both *ex situ* in gene bank as well as *in situ* among local farmers, as genetic erosion threat on tomato resources explained by decrease in number of current holders of local varieties and the low valuation they are subject to today.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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