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Strengthening the Resilience of Maize Producers in the Koulikoro Region against the Adverse effects of Climate Change

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Abstract: Koulikoro is the second economic region of Mali. Maize (Zea maize L.) is one of the most important food crops in this region where it is completely rainfed and dependent on changes in climate. Eighteen (18) drought tolerant maize varieties/hybrids were introduced into the farming environment to test their adaptability. The participatory varietal selection method was used to identify adapted varieties. This participatory varietal selection work and the study of the Genotype x Environment interaction led to the final choice of the following four (4) intermediate varieties/hybrids maize of 110 days, from seeding to harvest: IWDC3-SYN, PVA-SYN-22, FARAKO, DT-STR- SYN-Y and three (3) early maize varieties of 90 days: EVDT-99, DTE-STR-Y-SYN-POPC3, POP66-SR/ACR-91. These adapted maize genetic materials to the agro-ecological zones could be a solution to the problem of insufficient improved varieties in the Koulikoro region. On the other hand, the seed systems are oriented towards meeting market needs through the production of certified seeds according to international standards, while the majority of the producers regularly use seeds of local varieties taken from their own harvests. This is why the number of improved varieties has decreased. Eight (8) village cooperatives were trained in the maize community-based seeds production and distribution techniques. The outputs of the project were: the identified seven (7) drought-tolerant maize varieties/hybrids proposed to the extension services for vulgarization; the private network for the production and distribution of certified seeds of the improved varieties has been set up to ensure a continuous supply of the producers by the trained cooperatives. The FCRIT project has thus contributed to strengthening the resilience of the producers against the adverse effects of climate change.

Keywords: Maize, Climate Change, Adaptation Tests, Certified Seeds, Village Cooperatives, Community-Based Seeds

1. Introduction

Climate change models always predict an increased incidence of drought (Liet al. 2009). Under the influence of global warming, unusual weather phenomena have often created drought conditions for crops (Lisar et al, 2012; Dai et al, 2011). Drought leads to reduced productivity and crop growth, especially cereals (Daryanto et al, 2015). According to Burke and Lobell, (2010), the adaptation of varieties to the agro-climatic zones will not be attempted if the producers do not know about climatic changes and adjustments in agricultural practices to adept to climate variability. Some adaptations, such as change of sowing date, change of crop species, crop diversification, soil and water conservation, have been widely used. The rainfall system which is subject to drought, the diversification of fields, the different location of plots, can take advantage of the spatial variability of precipitation. The producers who will diversify their crops will be protected by secure land tenure, access to information, credit and labor supply (Hassan and Nhemachena 2008; Gbetibouo et al. 2010; Fosu-Mensah et al. 2012). As for the irrigation system, producers are protected by the existence of water, the increase in yield and the obtaining of a net income on the investment in inputs. It also allows farmers flexibility in sowing dates of varieties, crop species, duration and number of production seasons (Burke and Lobell 2010). Mali, which is located in the semi-arid zone, is not immune to drought holes and their direct consequences on crop yield and production (Traoré, 1986). These holes of drought have direct effects of atmospheric disturbances, causing rainfall deficits. The manifestation of end of growth cycle drought on the physiological life of crops leading to a drop in yield was reported by Sanou and Dabiré (2003). Other authors like Meeks et al, (2013); EL Sabagh et al, (2018) indicated that one of the most important factors limiting the growth and development of crops is the lack of water. It is therefore necessary to improve the drought tolerance of cereal crops to obtain high and stable yields. As a multidimensional stress, water limitation triggers a wide variety of plant responses; they range from the physiological and biochemical levels down to the molecular level (Yang et al, 2019; Dastogeeret al, 2018).

Maize (Zea mays L.) is the most important food crop in the sub-Saharan Africa where it is almost entirely rainfed and therefore increasingly dependent on the erratic rainfall of the West African sub-region. About 40% of the areas covered by maize in Africa face frequent droughts, with losses of up to half of the harvest (CIMMYT 2013). To reduce vulnerability and improve food security, the IITA Drought Tolerant Maize Project in Ibadan, Nigeria, developed several drought

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tolerant maize varieties and hybrids between 2007 and 2013. These genetic materials, in more drought tolerance, have other attractive characteristics such as resistance/tolerance to major diseases, high protein content and can give satisfactory yields under non-fertilizer conditions. They also have the advantage of having higher yields than local varieties (Smale et al, 2011; Tsedeke Abate, 2018), As far as maize is concerned, the characteristics sought for protection against climate change are the grains yield, drought tolerance and early maturity. Drought is one of the major factors limiting maize production in the Sahelian band of Mali. There are three types of drought: drought at the start of the rainy season, in the middle and at the end of the growth cycle. The first has an impact on the stand and can be corrected by resowing, while the second influences the biomass formation, which is also a grain yield factor. It is the end of cycle drought that is most important and dangerously compromises grain yield (Coulibaly 1987). The female flowering stage is the key stage in maize ear differentiation and development. The number of rows per ear and the number of grains per row depend on the differentiation of spikelets and flowers (Zhao et al, 2003). Thus, the growth and development of ears play an important role in maize yield. According to (Kaur et al 2017; Fang et al, 2017), external drought stimuli are perceived and captured by sensors on cell membranes, the signals are transmitted through multiple transmission pathways. Second, plants can regulate the expression of drought-sensitive genes to protect themselves against the adverse effects of external stimuli. Nakashima et al, (2014) stipulated that the products expressed by drought resistance/tolerance genes are mainly proteins involved in signaling cascades and regulation of protein kinases, protein phosphatases and transcription factors. According to Wang et al (2019); Chen et al, (2019); Ma et al, (2019), although there have been great advances in understanding maize ear differentiation and how drought stress affects gene transcription in the formation of the cob have been Known over the past few decades. At present, no progress has been made in understanding the molecular basis for combating long-term dryness.

2. Materials and Methods

2.1. Experimental sites

The Participatory Varietal Selection (PVS) and Seeds plots have been set up on On-farms in the six agricultural sectors of the Koulikoro region as indicated on the following geographical map.

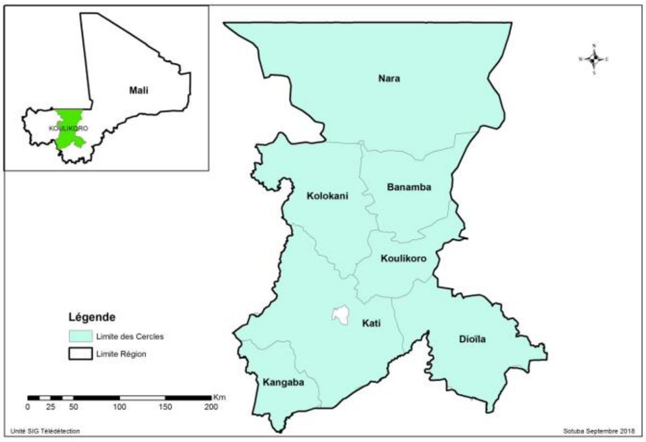

Figure 1: Map of the Koulikoro region (source: GIS, CRRA-IER-Sotuba 2018)

During the 2019-2020 agricultural campaign, the participatory variety selection plots composed of 18 varieties/hybrids of intermediate maize were installed in the agricultural sectors of Dioila, Kangaba and Kati for the North Sudanese zone and the plots of 10 early varieties/hybrids maize were installed in the agricultural sectors of Banamba, Kolokani, Koulikoro for the Sahelian zone.

2.2. Plant material 2019-2021

The maize varieties/hybrids used in the participatory varietal selection plots and the On-Farm Tests are shown in Table 1 below.

Table 1: Characteristics of maize varieties/hybrids used

Varieties/hybrids	Type	Grain color
Intermédiate Materials (110-120 days)		
M1124-6	Hybrid	Yellow
FARAKO	Hybrid	Yellow
FILANI	Hybrid	Yellow
LY1312-11	Hybrid	Yellow
PVA-SYN-22	OPV	Yellow
EVDTY2000STR	OPV	Yellow
DT-STR-SYN-2-Y	OPV	Yellow
WHITE/TZLCOMP1-W-F2	OPV	White
IWDC3-SYN	OPV	White
Z-DIPLOBC4C3-W/DOGONO/Z-DIPLO	OPV	White
Earley Materials (90-100 days)	**Type**	**Grain color**
2016TZE-YDTSTRQPm SYN	OPV	Yellow
2015 DTESTR-YSYN	OPV	Jaune

POOL 18-SR/ACR-4DMRESR-Y	OPV	Yellow
2009 TZE WPOPDTSTR	OPV	White
DTE-STR-Y- SYN-POPC3	OPV	Yellow
EYQH44	Hybrid	Yellow
EYQH22	Hybrid	Yellow
TZE-Y-DT-STR-QPM-SYN	OPV	Yellow
Extra-Earley Materials	**Type**	**Grain color**
TZEE-WPOP HDTC2STRC5	OPV	White
TZEE-W POP STR C5	OPV	White
2015 TZEE – WHDT STR	OPV	White

OPV= open pollinated variety

2.3. Agricultural inputs

Popularized fertilizers**:** Complex cereal, NPK (17N-17P-17K) and Urea (46N);
Organic fertilizer**;** Well-decomposed household waste, compost or park yard manure.
Herbicide: Primagold 500EC;
Fungicide: Red Caiman;

***2.4. Rainfall*:** Daily rainfall was recorded at all sites to determine the amount of rain that fell in order to characterize the rainfall pattern of the campaign.

2.5. Methods

The participatory research method was used by involving rural development actors (extensionists and producers) in the evaluation of the performance of technologies tested on the field. It was carried out during the inter-farmers' visits, organized in the different agricultural sectors of the Koulikoro region.

The participatory varietal selection, is a 3-year program, where:

- **The first year**: the producers choose in the selection plot or in a nursery of genetic materials, 0 to 4 varieties/hybrids of maize according to their own selection criteria.
- **The second year**: the varieties and hybrids of maize chosen will be tested in the peasant environment with the determination of the organoleptic and culinary characteristics to know their adaptability to the agro-ecological zones and the food habits of the producers.
- **The third year**: The final selection of maize varieties and hybrids is made after confirmation tests in the farming environment of the adaptability of the genetic materials chosen in the second year. Thus these materials are considered suitable and will be offered to the extension services for large-scale use in the region.

In 2019, six (6) plots of participatory varietal selection consisting of eighteen (18) varieties and hybrids of intermediate and early maize were installed in the agricultural sectors of the Koulikoro region, to enable producers to make their selection of varieties using their own selection criteria (Table 1).

In 2020 and 2021, respectively eighty-four (84) On-farm tests and thirty-six (36) On-farm demonstrations were conducted in the field on the intermediate and early maize varieties/hybrids chosen in 2019 by the producers. These were: FARAKO, IWDC3-SYN, PVA-SYN-22, DT-STR-SYN-2-Y compared to SOTUBAKA, the productivity control for intermediate maize; EVDT-99, DTE-STR-Y-SYN-POPC3, POP66-SR/ACR-91-SR, compared to BRICO the productivity control for early maize. Only the On-farm tests results are presented in this paper.

2.5.1. On-farm tests management

The project provided all the necessary inputs for the installation of the On-farm tests, namely seeds, fertilizers, and the fungicide product for seed treatment.

Choice of collaborating producers.
Volunteer producers from the 6 Agriculture Sectors of Kati, Dioila, Kangaba, Banamba, Kolokani and Koulikoro were selected to conduct the On-farm tests.

Experimental Design
The plots were dispersed Fisher blocks with 4 or 5 treatments. Each peasant's test represented a replication. The treatments were 20 m x 20 m or 400 m² separated by a 2 m aisle. The new introductions were compared to a productivity control as mentioned below. In each sector the tests were conducted by 12 producers.

On-Farm Tests

<u>Serie 1</u>: Intermediate maize

T1: SOTUBAKA (control)
T2: IWDC 3-SYN
T3: FARAKO
T4: PVA-SYN-22
T5: DT-STR-SYN-2-Y

<u>Serie 2</u>: Early maize

T1: BRICO (control)
T2: EVDT 99
T3: POP 66 / AC R 91SR
T4: DTE-STR-Y-SYN-POPC3

The On-farm Tests were conducted on plowed, well-leveled ground after picking up plant debris. All cultural operations were carried out in accordance with the recommendations of the monitoring protocol given to the field agent. The plots of On-farm tests sites were installed with easy access (roadsides) for the most part to facilitate the visits of the other producers in the village. The plots were sown with 3 seeds/hole at spacing of 80 cm between rows and 50 cm between holes for intermediate maize; 80 cm between rows and 75 cm between holes for early maize. Thinning was done at 2 plants/hill on the 15th day after sowing. Mineral fertilization covered 100 kg/ha of complex cereal NPK (17N-17P-17K) + 50 kg/ha of Urea (46N), i.e. 4 kg of complex and 2 kg of urea per elementary plot at sowing and 100 kg/ha of Urea at bolting, i.e. 4 kg per elementary plot 30 days after the first supply. The maintenance of the plots was ensured by 3 regular weeding at 15-day intervals. At harvest, the plots were harvested separately, the ears dispatched, dried and weighed to obtain the dry weight of the ears, then deseeded and weighed to obtain the dry weight of the grains or the yield (kg) per plot.

Collection of agronomic data. It focused on:

- Plowing date
- Sowing date
- Dates of basal fertilizer application (NPK) and second dose of urea
- Number of pockets raised
- Number of plants after thinning
- The vigor of the plants using a scale of 1 to 5 (1= good vigor and 5 = poor vigor)
- Appearance of ears from 1 to 5 (1= good appearance and 5 = bad appearance)
- Weight of cobs harvested
- Grain yield kg/plot
- Record of daily rainfall

2.5.2. Determination of the physico-chemical characteristics of the On-farm tests soils.

To know the physico-chemical characteristics of these soils, eighteen soil samples at a depth of 0-25 cm were taken from the agricultural sectors of Banamba, Dioïla, Kati, Kangaba, Kolokani and Koulikoro. They were analyzed by the Sotuba Soil-Water-Plant Laboratory.

2.5.3. Determination in the farming environment of organoleptic and culinary characteristics drought-tolerant maize varieties/hybrids tested in the field.

The aim of this activity was to evaluate the organoleptic characteristics (sensory or taste tests) of drought-tolerant maize varieties and hybrids in a farming environment. These tests were carried out to make known to the research, the criteria of consumer appreciation through the tasting of foods for general consumption (Tô, couscous, and Gninin kini). The study was conducted on five intermediate varieties (4 introduced varieties by the research and a control variety of productivity) and 4 early varieties (3 introduced varieties by the research and a control variety of productivity). The intermediate varieties were: IWDC3-SYN, PVA-SYN-22, FARAKO, DT-STR-SYN-Y and SOTUBAKA as control. The early varieties were: EVDT-99, DTE-STR-Y-SYN, POP66-SR/AC-R91 and Brico as control.

To carry out this organoleptic characterization, the following equipment was used: plastic cups, stainless steel cups, tray, scale, mortar, pestle, tea towel, grinder, pot, couscous maker, sieve of different meshes. The different transformations or preparations made were as follows:

Shelling: this step consists of separating the bran from the seeds by pounding in a mortar. During this stage, the following parameters were evaluated: the weight of the unshelled grains, the volume of water used for the shelling, the duration of the shelling, the color of the shelled grains, the weight of the shelled grains, the weight of the sound and the overall impression of the shelling.

Milling: it consists of grinding the shelled grains into flour. The following parameters were evaluated: ease of grinding, duration of grinding, color of flour, impression on the color of flour, roughness of flour, hardness of breaking, weight of flour, the weight of the break and the overall impression of the grind.

Cooking: is the actual preparation, the same quantity of flour was given for each variety to all the groups for the preparation of the dish. The parameters evaluated were: the volume of water used, the volume of potash used, the weight of the baobab leaf powder used, the preparation time, the weight of the remaining flour, the color of the dish, the weight of the dish and the overall appreciation of the dish.

Tasting: 25 people (men and women of all ages) took part in the tasting session of the varieties to be evaluated. The taster's information such as surname, first name, gender and age have been registered. Four evaluation criteria were used, namely color, taste, consistency or texture depending on the dish and the overall impression of the dish. The evaluation scores used for the criteria were: 1 = Problematic (not good), 2= Good, 3 = Very good.

2.5.5. Training of village cooperatives and extension technicians in seed production.

The village seed systems offer a range of local varieties that are accessible, of acceptable quality and at reasonable transaction costs. But these systems are also inefficient at generating new maize varieties that are essential for improving productivity. A better organization of the communities involved in the production of certified seeds and the establishment of a dynamic private network for the production and distribution of seeds would facilitate their access and availability for producers. To do this, eight (8) village cooperatives and twenty (20) extension technicians were trained in community-based maize seeds production techniques in the Koulikoro region.

2.5.6. **Data analysis**: The data collected was analyzed using the statistical software MSTATC using the method of analysis of variance, the classification of the means with the Duncan test at the 5% threshold, Excel for the graphs and the GenStat for studying the Genotype x Environment interaction.

3. Results

3.1. Rainfall pattern

In general, in the past three years, the rainfall of the region was characterized by a frequency and low intensity of rains during the months of July, August and September with a maximum in August. A fairly good distribution of rainfall from July to September (figures 2 and 3). An early end of the rains in October has always been observed in all sectors. This phenomenon has led to premature drying of the plants and was an illustration of the harmful effects of climate change in the Koulikoro region (photo 1).

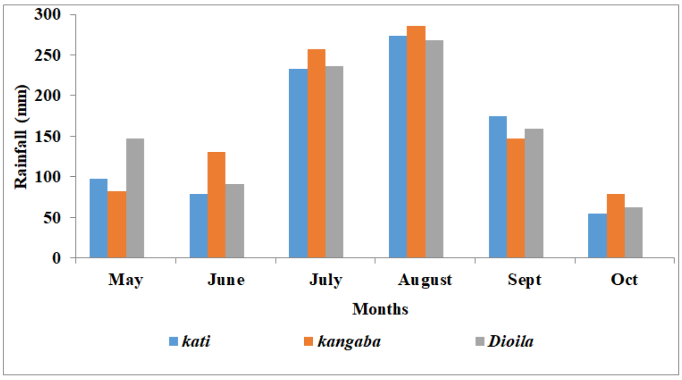

Figure 2: Average monthly rainfall over 3 years in the Dioila, Kangaba and Kati sectors

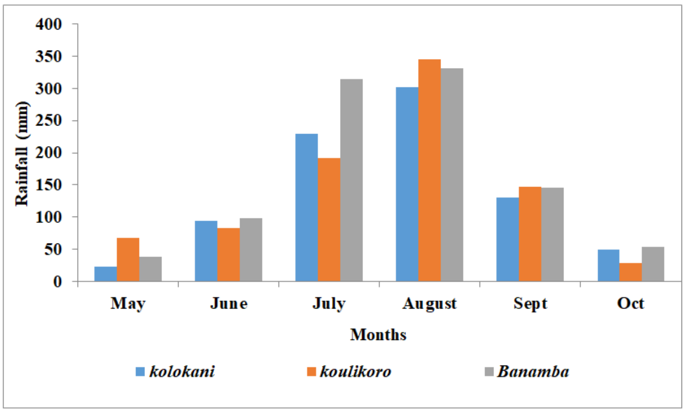

Figure 3: Average monthly rainfall over 3 years in the sectors of Banamba, Kolokani, Koulikoro.

Photo 1: Intermediate maize test, Farmer, Lassine Diarra, village of Missango, agricultural sector of Dioila, 2021.

3.2. The Participatory Varietal Selection (PVS) of the drought-tolerant maize varieties and hybrids.

In 2019, during the participatory varietal selection sessions, the producers made their choices from eighteen (18) varieties and hybrids of early and intermediate maize submitted for their assessment. They chose maize varieties and hybrids using the following criteria: the size and shape of maize grain; number of ears/plants; grain size, color and virtuousness; plant vigor and height; drought tolerance; Earliness, etc. (Figures 4, 5). The selection criteria based on the agronomic traits are very important in the evaluation of the germplasm in the field.

In the North Sudanian zone (Kati, Kangaba, and Dioila sectors), the producers used some of the criteria mentioned above to choose the following 4 intermediate cycle maize varieties/hybrids: LY1312-11, IWDC3-SYN, FARAKO, FILANI (figure 4).

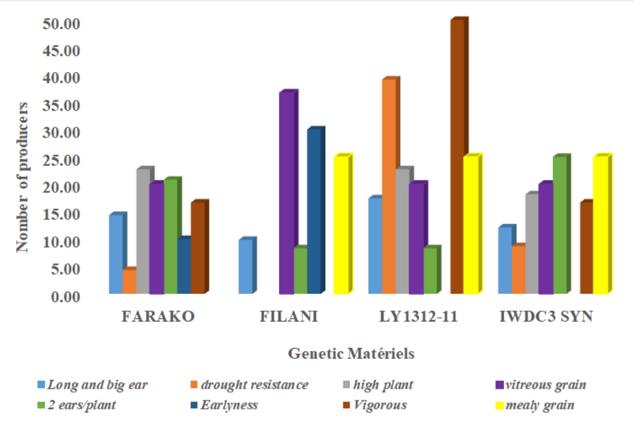

Figure 4: Intermediate maize cycle varieties and hybrids chosen by the producers and the selection criteria, North Sudanian zone.

In the Sahelian zone (Kolokani, Banamba and Koulikoro sectors), the producers used some of the criteria mentioned above to choose the following 4 Early cycle maize varieties/hybrids:
EYQH-22, EYQH44, DTE STR-Y SYN POPC3, 2015 TZEE-WHDT-STR (figure 5).

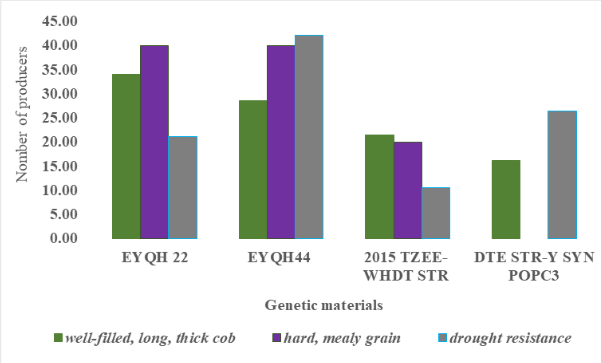

Figure 5: Early cycle varieties and hybrids maize chosen by the producers and the selection criteria, Sahelian zone

3.3. Study of the performance of the tested maize varieties and hybrids.

To concretize the choices of the producers, the study of the Genotype x Environment interaction was carried out. Its purpose was to know the stability of the variety and its ideal environment and to highlight the contributions of the variety and its environment in the variation in yield.

3.3.1. North Sudanian Zone, Agriculture Sectors of Dioila, Kati and Kangaba.

The analysis of variance for the average yields of maize varieties and hybrids showed no statistical difference between the varieties in the 2 growing conditions of mineral fertilizer and organic manure in the agricultural sectors of Kati, Kangaba and Dioila. The best yields were obtained by the PVA-SYN-22 variety in mineral fertilizer conditions with 4784 kg/ha and in organic manure conditions by the hybrid EYQH22 with 4882 Kg/ha (Table 2).

Table 2: Analysis of variance for average yields of drought-tolerant intermediate cycle maize, 2019.

Varieties/hybrids	Yield (Kg/ha)	
	Mineral fertilizer	Organic ftilizer
2009 TZE W POP DTSTR	3340	3307
2015 DTE STR- Y SYN	3626	4170
2016TZE-YDTSTRQPm SYN	3764	2911
DT SY N2-Y	3948	3803
DTE STR-Y SYN POPC3	4502	2922
EVDTY 2000 STR	3526	3401
EYQH22	4740	4882
EYQH44	3436	3028
Farako	4556	4039
FILANI	3946	4174
IWDC2SYN	3964	3570
LY1312-11	3622	4131
M1124-6	4456	4133
POOL 18-SR/ACR-MRE SR-Y	1955	1374
PVA SYN22	4784	2965
SOTUBAKA	3348	3051
WHITE DTSTRS YN/TZLCOMP1-W-F2	3576	2540
Z-DIPLOBC4C3- W/DOGONO/Z-DIPLO	3512	3040
Overall average	**3811**	**3414**
Significance	**NS**	**NS**
CV%	**34,6**	**24.7**

NS = No significance; CV = Coefficient of variation

In the mineral fertilizer conditions, the most stable varieties were EYQH22, FARAKO, DTE-STR-Y-SYN-POPC3 and M1124-6; the ideal environment for the tested varieties was the Kati agriculture sector located in the small circle not far from the arrow. The principal component 1 (PC1) indicated that 66.22% of the yield variation was due to the environment and 33.78% of yield variation was due to variety (figure 6).

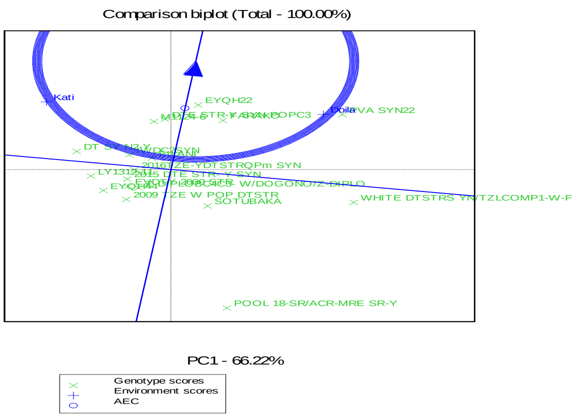

Figure 6: Genotype-Genotype/Environment (GGE) biplot, Performance Stability of the varieties/hybrids maize (mineral conditions).

In the organic fertilizer conditions, the study of the Genotype x environment interaction showed that the most stable varieties were 2009 TZE-W-POP-DT-STR, DTE-STR-Y-SYN-POPC3, DT-STR -Y-SYN and WH-DT-STR-SYN/TZLCOMP1-W-F2. The ideal environment for the tested varieties was the Kati agriculture sector located in the small circle not far from the arrow. The principal component 1 (PC1) showed that 88.26% of the yield variation was due to the environment and 11.74% of the yield variation was due to variety (Figure 7).

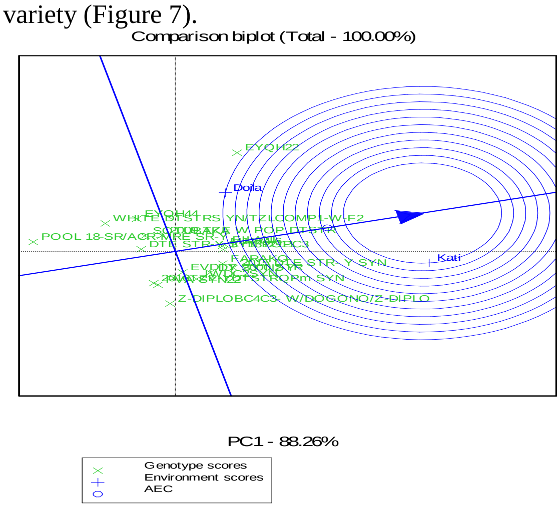

Figure 7: Genotype-Genotype/Environment (GGE) biplot, Performance Stability of the varieties/hybrids maize (organic conditions)

Indeed in the North Sudanian zone, this study showed that for the 2 cultivation conditions (mineral and organic fertilizations), the Kati Agriculture Sector was the ideal environment for the cultivation of the tested genetic materials.

3.3.2. Sahelian zone, agricultural sectors of Banamba, Kolokani and Koulikoro

The analysis of variance for the yields of Early maize varieties and hybrids showed significant differences between the varieties under mineral fertilizer conditions. The best yield was obtained by the DTE-STR-Y-SYN-POPC3 variety with 4211 kg/ha. However, there were no significant differences between these genetic materials under organic manure conditions (Table 3).

Table 3: Analysis of variance for average yields of drought-tolerant early cycle maize 2019

Varieties/Hybrids	Yield (Kg/ha)	
	Mineral fertilizer	Organic orftilizer
2009 TZE STR-Y SYN POPC3	3782	1952
2015 DTE STR- Y SYN	3410	2357
2015TZEE –WHDT STR	4142	2786
2016TZE-YDTSTRQPm SYN	2715	1931
BRICO	2480	2143
DTE STR-YSYN POPC3	4211	2419
EYQH22	3193	2756
EYQH44	3804	2333
POOL 18-SR/ACR-MRESR-Y	1771	1514
TZEE-W POP STRC5	3199	2830
TZEE-WPOP HDTC2 STRC5	2183	2151
Overall average	**3172**	**2288**
Significance	**S**	**NS**
LSD	**1438,4**	**-**
CV%	**26,6**	**28**

LSD = least significant difference; CV = Coefficient of variation

In the mineral manure conditions, the study of the Genotype x environment interaction showed that the most stable varieties were: 2015TZEE-WHDT-STR, DTE-STR-Y-SYN, 2009 TZE-STR-Y-SYN-POP-C3. Banamba was the best agricultural sector for these varieties. The principal component 1 (PC1) showed that 67.18% of the yield variation was due to the environment and 25.92% of the yield variation was due to variety (Figure 8).

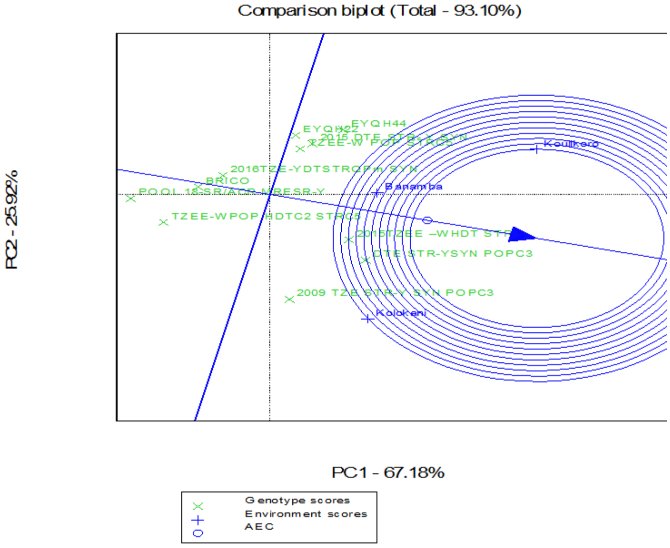

Figure 8: Genotype-Genotype/Environment (GGE) biplot, Performance stability of the varieties/hybrids maize (mineral conditions).

In the organic manure conditions, the study of the Genotype x environment interaction showed that the most stable maize varieties and hybrids were 2015TZEE-WHDT-STR, EYQH 22, EYQH44, 2009 TZE STR-Y-SYN-POPC3 and TZEE-WPOP-HDTC2-STRC5. Banamba agricultural sector was the best area for the tested varieties (figure 9). The principal component 1 (PC1) indicated that 79.85% of the yield variation was due to the environment and 14.52% of the yield variation was due to variety (Figure 9).

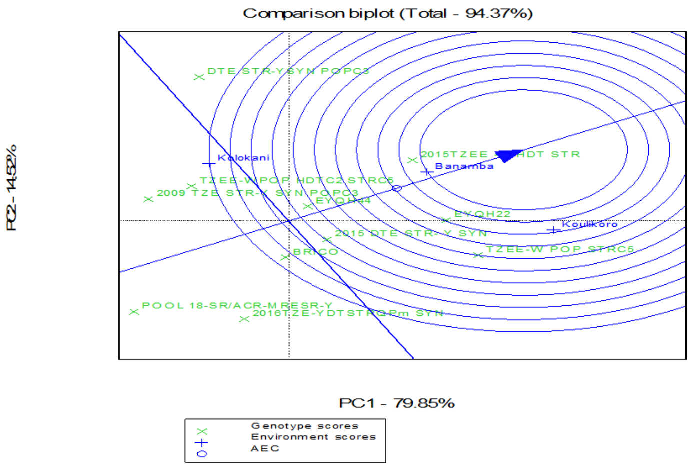

Figure 9: Genotype-Genotype/Environment (GGE) biplot, Performance Stability of the maize varieties/hybrids maize (organic conditions).

Indeed in the Sahelian zone, the study showed that for the 2 cultivation conditions (mineral and organic fertilizers), the Banamba Agriculture Sector was the ideal environment for the cultivation of early tested genetic materials tolerant to drought.

In summary this work led to the identification of the maize varieties and hybrids to be tested on On-farm during the following two years were:

- **North Sudanian zone 800-900 mm, agriculture sectors of Dioila, Kati and Kangaba**: intermediate cycle maize (110-120 days): IWDC3-SYN (variety) FARAKO (hybrid), PVA-SYN-22 (variety) and DT-SYN-2-Y (varieties).
- **The Sahelian zone 600-700 mm**, agricultural sectors of Banamba, Kolokani, Koulikoro: early cycle maize (90-100 days): DTE-STR-Y-SYN-POPC3 (variety), EVDT-99 (variety), POP66-SR/ACR-91-SR (variety).

3.4. Adaptation tests of maize varieties/hybrids of intermediate and early cycles, 2020, 2021.

The above-mentioned drought-tolerant maize varieties and hybrids, selected by the producers in 2019, were tested on On-farm in 2020 and 2021 in comparison with a productivity control to find out their adaptability to the region's agro-ecological zones of Koulikoro region. The On-farm tests results only are presented in this paper. These of 2021 were the On-farm demonstrations in the fields.

In the North Sudanian zone, the statistical analysis of the data collected on the On-Farm tests showed significant differences between the varieties for the measured parameters with the exception of plants height with a variation coefficient of 24.34%. The improved varieties IWDC3-SYN, PVA-SYN-22, FARAKO showed their superiority compared to DT-STR-SYN-2-Y and the productivity control SOTUBAKA for the yield/ha, the weight of ears/ha and the number of plants after thinning (Table 4). Thus in these area i.e. Kati, Dioila, Kangaba sectors, the new varieties showed a good performance compared to the productivity control (Table 4).

Table 4: Analysis of variance for yield and yield components means of intermediate cycle maize, 2020.

Varieties/Hybrids	NPR/HA	*NPAT*/HA	PH (m)	EW (Kg/ha)	Yield (kg/ha)
SOTUBAKA (control)	21672 ab	39128 bc	2,03	2622 bc	2019 bc
IWDC3-SYN	22776 a	41296 ab	2,08	2940 ab	2241 ab
FARAKO	22792 a	42280 a	2,05	3045 a	2336 a
PVA-SYN22	21652 ab	38404 c	2,07	2764 ab	2092 abc
DT-STR-SYN-2-Y	21360 b	37144 c	2,98	2325 c	1840 c
Significance	**S**	**S**	**NS**	**S**	**S**
Overall average	**22050**	**39650**	**2,04**	**2739**	**2106**
CV%	**9.29**	**11.75**	**10.64**	**23.74**	**24.34**
LSD	**1150.16**	**2616.66**	**-**	**365.14**	**287.77**

NPR = number of pockets raised; NPAT= number of plants after thinning; PH=plant height; EW = ear weight; NS=not significant; S=significant at the 5% level; CV= coefficient of variation; LSD= least significant difference.

For the Sahelian zone, statistical differences were observed between yield components such as the number of raised pockets/ha, the number of plants/ha after thinning and the height of the plants. However, there were no significant differences between the new introductions and the BRICO, the productivity control for yield/ha and ear weight/ha. This indicated an equality of performance of the tested varieties in Banamba, Kolokani, Koulikoro agricultural sectors
(Table 5). It was noticed that the new varieties had more green leaves at harvest (on the right) than the control (on the left), characteristic of drought tolerance (photo 3) below.

Table 5: Analysis of variance for yield and yield components means of the early maize varieties, 2020.

Varieties/Hybrids	NPR/HA	*NPAT*/HA	PH (m)	EW (Kg/ha)	Yield (kg/ha)
BRICO (témoin)	22925 ab	37483 a	1,95 a	2265	1766
EVDT 99	24111 a	39417 a	1,99 a	2537	1969
POP66 SR/ACR 91 SR	22983 ab	38511 a	1,81 b	2383	1872
DTE-STR-Y-SYN POPC3	21753 b	33994 b	1,91 ab	2502	1942
Signification	**S**	**S**	**S**	**NS**	**NS**
Overall average	**22943**	**37354**	**1,92**	**2422**	**1887**
CV%	**13.55**	**16.62**	**12.22**	**27.19**	**28.18**
LSD	**1453.31**	**293.01**	**0.109**	**-**	**-**

NPR = number of pockets raised; NPAT= number of plants after thinning; PH=plant height; EW = ear weight; NS=not significant; S=significant at the 5% level; CV= coefficient of variation; LSD= least significant difference

Photo 2: Early maize, Producer, Bah Diarra, Mafeya village, Sector, Dioila, 2020.

Notice: Despite the degree of drought, the new varieties kept more green leaves, synonymous of stress tolerance).

The three (3) years of on-farm testing of drought-tolerant varieties/hydrids maize identified desirable and adapted genetic materials for strengthening the resilience of the producers against the adverse effects of climate change. They were as follows:

- **North Sudanian zone: agricultural sectors of** Dioila, Kati and Kangaba. The below four (4) intermediate cycle varieties/hybrids maize of 110 to 120 days from planting to harvest were selected for popularization: IWDC3-SYN, PVA-SYN-22, DT-STR-SYN-2-Y and FARACO
- **Sahelian zone: agricultural sectors of** Banamba, Kolokani and Koulikoro. The below three (3) Early cycle varieties/hybrids maize of 90 to 100 days from planting to harvest were selected for popularization: EVDT 99, DTE-STR-Y-SYN-POPC3, POP-66-SR/ACR 91-SR.

3.5. Determination of the physico-chemical characteristics of the On-farm Tests soils

Eighteen (18) composed soil samples from the On-farm Tests were submitted to the Soil-Water-Plant laboratory of the Regional Agronomic Research Centre of Sotuba for analysis. The results are recorded in Table 5 below.

3.5.1. Physical characteristics or Texture

Particle size analysis showed that the soils are leached ferruginous with a medium texture (sandy-loamy to clayey-loamy) quite poor in clay (Table 6). They are suitable for dry crops, horticulture and arboriculture since they are deep soils without armor and without shell. The irrigation facilities are needed for the low slope parts to avoid the effects of water erosion.

3.5.2. Physico-Chemical Characteristics

The pH measurements on the eighteen soil samples taken at the depth (0–25 cm) in the different localities, showed that all these soil samples are classified in the pH range optimal (pH = 5.55 to 6.32). These pHs are well indicated for the availability of nutrients for most plants. These soils do not present any problem of acidity, therefore no intake of calcium elements (Table 6).

3.5.3. Organic matter (OM)

From the eighteen samples, five samples gave slightly high organic carbon values of (0.62 to 1.10% which are below the critical threshold of 0.6%). These samples are observed on the second plots of Banamba, Kati and Koulikoro and on the third plots of Kati and Kangaba. All the other plots have a fairly low organic carbon content (0.14 to 0.48%), well below the tolerance threshold. At this stage, these soils are said to be poor in organic matter (Table 6). It is necessary to bring them organic manure at the rate of 5 to 10 tons/ha according to the producer’s capacity. These doses are recommended and popularized.

3.5.4. Total Nitrogen (N)

All the eighteen samples taken at the depth (0-25 cm) on the different plots showed a low nitrogen content of 0.02% to 0.04% which is well below the critical threshold (1.2%). At this stage, these soils are said to be low in nitrogen content (Table 6). It is necessary to provide these soils with the popularized doses of the mineral nitrogen fertilizer. Example, for maize crop: 100 kg per hectare of complex cereal (17N-17P-17K) and 150 kg per hectare of urea (46N-0P-0K) must be added. This supply is made in two fractions (100 kg/ha of complex cereal + 50 kg/ha of urea at planting time and 100 kg/ha of urea 30 days after the first supply.

3.5.5. C/N ratio

The analysis results of the eighteen samples taken from the different plots at a depth of 0-25 cm showed that the C/N ratio is greater than 20 in three of the samples where there is more organic matter for little nitrogen. The phenomenon of "nitrogen starvation" is observed in these plots. The C/N ratio is equal to 10 in two samples, which means that the decomposition is maximum on these plots. In four plots the C/N ratio is less than 15, which means that the rate of decomposition of organic matter is increasing. The C/N ratio is between 15 and 20, which means that the nitrogen requirement allows good decomposition in the four plots of the study. The C/N ratio is less than 10 in five samples, which explains why there is more nitrogen for little organic matter, so the decomposition is too rapid (Table 6).

3.5.6. Available phosphorus (P)

Four samples out of the eighteen analyzed samples presented a high rate of available phosphorus of 8.05 to 40.18 ppm which are above the critical threshold (7 ppm). However, the remaining fourteen samples, i.e. 78% of the analyzed samples are low in available phosphorus (Table 6). These soils must be supplied with mineral phosphorus fertilizers. In rice culture, it is necessary to bring to these soils, the popularized dose of phosphorus fertilizer (100 kg/ha of Diammonium phosphate (DAP): 18N-46P-0K and 150 kg/ha to 200 kg/ha of NPK: 16N-26P-12K.

Indeed, the results of these analysis showed that the soils of the On-farm tests were generally poor according to the indicators chosen and their tolerance thresholds. All of these soils are very weakly acidic (pH 5.55 to pH 6.32) so they are not subject to the adverse effects of aluminum and iron on phosphorus availability and plant growth. These soils are mostly poor in organic matter, because they have a rate below the critical threshold of 6 g per kg of soil. This same trend is observed with respect to available phosphorus and total nitrogen. Additional inputs of organic matter PROFEBA enriched with Tilemsi Natural phosphate (PNT) would contribute to validly improving the management of the fertility of these soils. With an average pH, a low MO content, a relatively poor N content with an average texture quite poor in clay, these types of soils are better suited to the cultivation of annual plants (millet, sorghum, maize, groundnuts, cowpeas, wheat, arboriculture) and horticulture.

3.5.7. **Table 6**: Soil analysis results of the On-farm tests

N° Laboratory	1	2	3	4	5	6	7	8	9	10
Appliquant Specificatio	Banamba E1 :0-25cm 09/07/21	Banamba E2 :0-25cm 09/07/21	Banamba E3 :0-25cm 09/07/21	Dioïla E1 :0-25cm 08/07/21	Dioïla E2 :0-25cm 08/07/21	Dioïla E3 :0-25cm 08/07/21	Kati E1 :0-25cm 07/07/21	Kati E2 :0-25cm 07/07/21	Kati E3 :0-25cm 07/07/21	Kangaba E1 :0-25cm 07/07/21
pH (water)	6.20	6.21	6.31	6.05	5.81	5.62	5.55	5.68	5.95	6.27
Organic Carbone % C	0.20	0.62	0.19	0.18	0.48	0.44	0.39	0.63	0.62	0.39
total Nitrogen % N	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04
C/N Ratio	10	21	6	6	16	15	13	16	15	10
Available Phosphorus ppm P	6.65	0.28	6.93	0.98	2.38	2.31	6.37	10.01	4.62	26.04
Sand %> 0.05mm	47	70	82	88	60	69	80	43	56	70
Fine silt % 0.05-0.002mm	48	13	10	5	19	12	10	23	27	19
Clay % < 0.002mm	5	16	8	7	21	19	10	31	15	12
Textural class	Lf	LS	SL	SL	LAS	LS	SL	LA	LS	LS

N° Laboratory	11	12	13	14	15	16	17	18
Appliquant Specificatio	Kangaba E2 :0-25cm 07/07/21	Kangaba E3 :0-25cm 07/07/21	Kolokani E1 :0-25cm 07/07/21	Kolokani E2 :0-25cm 07/07/21	Kolokani E3 :0-25cm 07/07/21	Koulikoro E1 :0-25cm 07/07/21	Koulikoro E2 :0-25cm 07/07/21	Koulikoro E3 :0-25cm 07/07/21
pH (water)	6.10	6.09	6.00	6.29	6.32	6.20	6.13	6.24
Organic Carbone % C	0.39	0.66	0.14	0.24	0.37	0.38	1.10	0.18
total Nitrogen % N	0.04	0.02	0.03	0.03	0.02	0.02	0.04	0.02
C/N Ratio	10	22	5	8	18	19	27	9
Available Phosphorus ppm P	2.45	4.48	1.68	3.57	6.02	8.05	5.95	40.18
Sand %> 0.05mm	42	38	58	65	60	50	39	94
Fine silt % 0.05-0.002mm	51	33	27	21	27	47	42	2
Clay % < 0.002mm	8	27	15	13	13	3	19	4
Textural class	LS	LA	LS	LS	LS	LS	LS	SL

Source : SEP/Laboratory IER
BP: 262 TEL: 44 38 49 75
SERIE N°: U007 (2022)

3.6. Determination of the organoleptic characteristics of maize varieties and hybrids tested in the farming environment.

The results of the tasting works on the intermediate maize varieties in the village of Gouana, in Dioila agricultural sector are presented and those of the village of Torokorobougou, in Kolokani sector on the Early materials are not presented with the exception of the work conclusion. The preparations of the different main dishes of the Koulikoro region are indicated below.

a. Preparation of Tô

The results obtained (Table 7) showed that the control was the variety which had the best shelling yield (92%) compared to the other varieties. Variety IW-DC-3-SYN was the variety that had the lowest shelling yield (88%) and produced more bran (1.6 kg). It had the lowest milling yield (81%) and was first in the overall tasting. Based on all the assessment criteria (consistency, color, taste and general assessment) of the sensory evaluation (Figure 10), it was noticed that the varieties IW-DC-3-SYN, FARAKO, PVA-SYN -22 (V1, V2 and V3) were the best appreciated by tasters. The ranking during the overall tasting was as follows: IW-DC-3-SYN, FARAKO, PVA-SYN-22, SOTUBAKA, and DT-STR-SYN-2-Y (photo3).

Table 7: Technological parameters of the different intermediate varieties

Name	Var 1 : IWDC-3-SYN			Var 2 FARAKO			Var 3 PVA-SYN-22			Var 4 DTS-TR-SYN			Control SOTUBAKA		
	Tô	Cou	Kini	Tô	Cou	Kini	Tô	Cou	Kini	Tô	Cou	Kini	Tô	Cou	Kini
%Shelling yield	88			91			89			91			92		
Shelling time; (min)	16			14			11			14			13		
Water used for decorating (ml)	1333			1283			1450			1067			1333		
Ease of shelling	3			2			3			1			3		
Sound weight; (g)	1600			1500			1533			1033			1333		
% Milling Yield	81			85			88			87			85		
Cooking time ; (min)	32	33	22	32	37	25	/	22	22	28	25	22	26	19	22
Consistancy/ Texture	3	3	3	3	2	3	3	3	2	3	3	3	3	2	3
Cooking Water (ml)	6100	1200	3200	4910	745	3200	6050	875	3150	6200	750	3075	5950	575	3250
Plate weight (g)	6800	3200	3550	6000	2700	3450	6400	2600	3300	6400	2400	3900	6800	2300	3800
Tasting rank	1st	1st	1st	2nd	5th	5th	3rd	2nd	3rd	5th	4th	2nd	4th	3rd	4th

V = variety; cou = couscous; kini = Gningnin kini

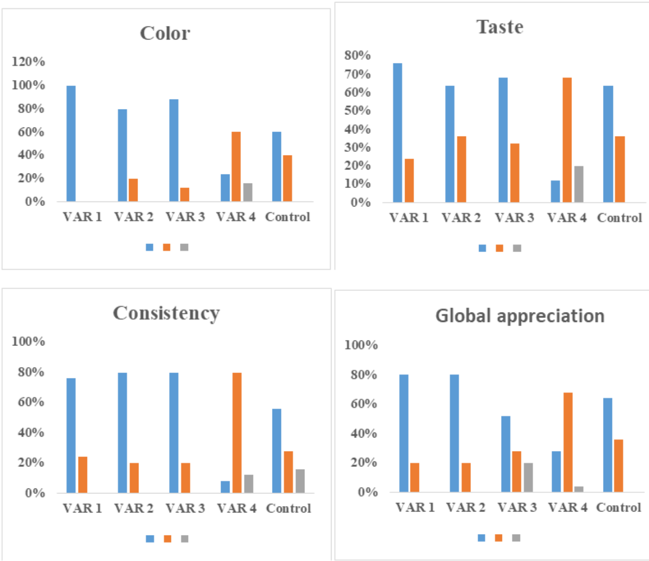

Figure 10: Appreciation of the evaluation criteria for the prepared Tô.

b. Couscous preparation

The results obtained (Table 7) showed that the control SOTUBAKA was the variety which had the best yield at shelling (92%) compared to the other varieties. The IW-DC-3-SYN variety is the variety that had the lowest shelling yield (88%), more bran (1.6 kg) and had the lowest milling yield (81%). This preparation also revealed that the variety IW-DC-3-SYN occupied the first choice of the overall tasting. For this preparation, the classification was as follows: IW-DC-3-SYN, PVA-SYN-22, SOTUBAKA, DT-STR-SYN-2-Y, and FARAKO. Based on the appreciation criteria (texture, color, taste and global appreciation) of the sensory evaluation (figure11), the varieties IW-DC-3-SYN, PVA-SYN-22, SOTUBAKA were the best appreciated by tasters. Variety IW-DC-3-SYN outperformed PVA-SYN-22 in texture and color. PVA-SYN-22 exceeded SOTUBAKA (the control) in terms of texture.

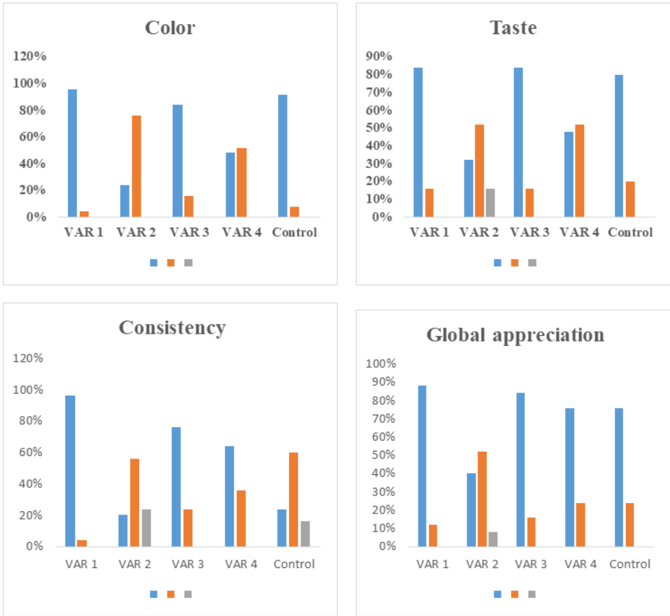

Figure 11: Appreciation of the evaluation criteria for the prepared Couscous

c. Preparation of broken grains (Gningnin kini)

The results obtained (Table 7) show that the control is the variety with the best shelling yield (92%) compared to the other varieties. IW-DC-3-SYN was the variety that had the lowest shelling yield (88%), more bran (1.6 kg) and had the lowest milling yield (81%). The ranking during the overall tasting was as follows: IWDC3-SYN, DT-STR-SYN-2-Y, PVA-SYN-22, SOTUBAKA, and FARAKO. Based on the appreciation criteria (texture, color, taste and global appreciation) of the sensory evaluation (Figure 12), the varieties IWDC3-SYN, DT-STR-SYN-2-Y, PVA-SYN-22 were the most appreciated by the tasters. The IWDC3-SYN variety presented the best characteristics compared to all the other varieties.

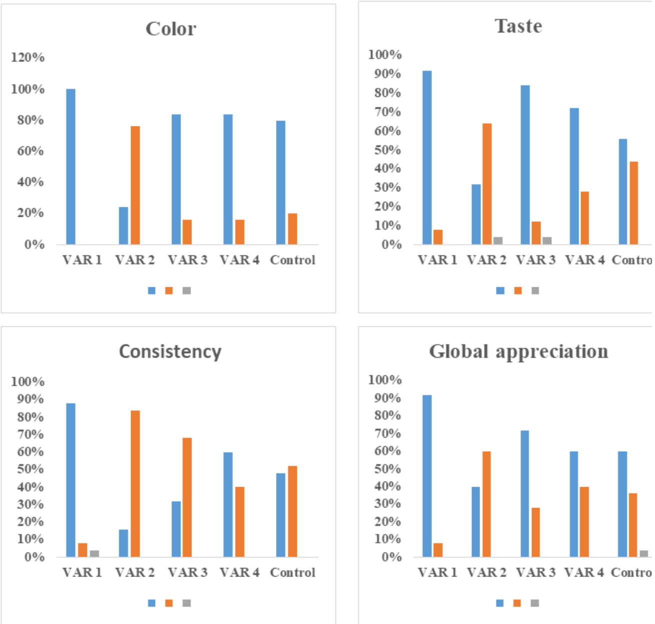

Figure 12: Appreciation of the evaluation criteria for the prepared broken grains (Gningnin kini)

The tasting works for the drought-tolerant varieties and hybrids maize is shown in the photo 3 below.

Photo 3: Preparation of tô: 1= Shelling the maize; 2= Puting maize meal porridge in the pot; 3=Tuning the viscosity of the tô; 4 = 5 ready Tô dishes of the tested varieties, from right to left V1, V2, V3, V4, control; 5 = Tô tasting by the taster.

In the northern Sudanian zone, represented by the village of Gouana in the agricultural sector of Dioila, among the 5 intermediate varieties, IWDC3-SYN was the variety that maintained its first ranking for all the preparations made (Tô, couscous, Gningnin kini). On the other hand, the DT-STR-SYN-2-Y variety occupied the second place in the preparation of broken grains or Gningnin kini.

As far as the Sahelian zone is concerned, the same tasting works were done on the Ealy maize varieties in the village of Torokorobougou Ouest in the Kolokani sector. The same types of preparation (Tô, couscous, Gningnin kini) were used. The 4 early varieties evaluated were assessed in the order: DTE-STR-Y-SYN-POPC3, BRICO, EVDT99, POP 66 SR/AC R91.

This study highlighted the adaptability of the tested varieties to the eating habits of the region.

3.7. Training of village cooperatives of extension technicians.

A total of 433 maize producers were trained in the 6 agricultural sectors of the Koulikoro region with an average of 36 producers per sector. They were theoretically and technically trained in the community-based maize seed production techniques. The training focused on the technical itineraries for seed production, practical advices to ensure the quality of the produced seeds, seeds certification process, etc. (photos 4, 5).

Photo 4: Training session of the Benkady Cooperative in the village of Kiniélé, agriculture sector of Kangaba, 2019

Photo 5: Mr. Bounama Sacko, LABOSEM technician making observations on the Falakan cooperative seeds plot with the producers, agricultural sector of Kolokani,

4. Discussion

During the years 2019 to 2021, the insufficiency, the bad distribution and especially the early end of the rains in October in all the agricultural sectors of the Koulikoro region were the cause of the low yields obtained. The premature drying of the plants in October did not favor the normal development of the maize plant. The average yield levels were for intermediate maize from 2336 Kg/ha to 1840 Kg/ha in the North Sudanian zone and from 1969 kg/ha to 1766 kg/ha for the Sahelian zone. This is in agreement with Coulibaly, (1987) who said that drought is one of the important factors limiting maize production in the North Sudanian and Sahelian bands of Mali. The end-of-cycle drought is the most important and dangerously compromises grain yield. According to Lisar et al, 2012; Dai et al, 2011, under the influence of global warming, changes in climatic conditions create unusual weather phenomena often imposing drought on crops.

In the North Sudanian zone, despite the delay in sowing in July, and the early stoppage in October, the 3 new intermediate maize varieties, FARAKO, IWDC3-SYN, PVA-SYN-22, proved to be superior to the productivity control variety SOTUBAKA with respectively average yields of 2336 kg/ha; 2241 Kg/ha, 2092 Kg/ha and 2019 kg/ha in the different localities. These results are consistent with those obtained by Smale et al. (2011); Daryanto et al, (2015). They said that from an agricultural perspective, drought often results in lower productivity and especially for cereals crops. The lowest yield was obtained by the productivity control SOTUBAKA. This mirrors the words of Tsedeke Abate, (2018) who stated that drought-tolerant maize has the advantage to have higher yields than local material.

In the Sahelian zone, the same phenomenon of climatic hazards which characterized the 3 agricultural campaigns was observed and greatly affected the average yields obtained from the early varieties which oscillated between 1969 Kg/ha and 1766 Kg/ha. In this zone, the 3 new varieties of early maize EVDT 99, DTE-STR-Y-SYN-POPC3, POP66-SR-Y-SYN-POP-C3 and the productivity control BRICO had an equal behavior or had the same performance with respectively yields of 1969 kg/ha, 1942 kg/ha, 1872 kg/ha and 1766 kg/ha.

Generally speaking, in these 2 agricultural zones of the Koulikoro region, the yields obtained were far below the known potential of the tested maize varieties (5 to 6 T/ha for the intermediate cycle maize and 3 to 4 T/ha for early cycle maize). These results are in agreement with the those of the work of Meeks et al, (2013); EL Sabagh et al, (2018). They indicated that one of the most important limiting factors of the growth and development of maize is the lack of water and therefore it is necessary to improve the drought tolerance of cereal crops to obtain high and stable yields.

Furthermore, the soil analysis results revealed that these soils were mostly poor in organic matter, having a rate below the critical threshold of 6 g per kg of soil. This same trend was observed with respect to available phosphorus and total nitrogen. Thus, these results confirmed the extreme poverty of the soils in terms of organic matter, available phosphorus and total nitrogen, which also had a negative impact on the yields obtained. To do this, the study of the Genotype x Environment interaction was done to identify stable varieties and the ideal place for their cultivation. Thus the Kati sector was the ideal environment for the intermediate cycle maize and the Banamba sector for early cycle maize. As a multidimensional stress, water limitation triggers a wide variety of plant responses; they range from the physiological and biochemical levels down to the molecular level (Yang et al, 2019; Dastogeeret al, 2018). According to Kaur et al. (2017); Fang et al, (2017), thirst external drought stimuli are perceived and captured by sensors on cell membranes, signals are transmitted through multiple transmission pathways. Second, plants can regulate the expression of drought-sensitive genes to protect themselves against the adverse effects of external stimuli. Nakashima et al, (2014) mentioned that the products expressed by drought resistance/tolerance genes are mainly proteins involved in signaling cascades and regulation of protein kinases, protein phosphatases and transcription factors. The same is true for functional proteins. The female flowering stage is the key stage in maize ear differentiation and development. The same is true for the number of rows per ear and the number of grains per row, which depend on the differentiation of spikelets and flowers (Zhao et al, 2003). Therefore, the growth and development of ears plays an important role in maize yield. According to Wang et al, (2019; Ma et al, (2019), although there have been great advances in the understanding of maize ear differentiation, so far no progress has been achieved in understanding the molecular basis for long-term fighting against drought. Maize is the most important food crop in sub-Saharan Africa, where it is almost entirely rainfed and, therefore, increasingly dependent on the erratic rainfall of the West African sub-region. About 40% of the areas covered by maize in Africa often face occasional droughts in which yield losses can go up to half of the harvest (CIMMYT 2013). The years of 2019 to 2021 were characterized by a succession of drought periods, small amounts of water and an early end of the rains which did not favor the normal development of maize plants in the Koulikoro region. Thus, the results obtained are consistent with those obtained by Badu-Apraku et al. (2012). They mentioned that under drought conditions, agricultural traits or yield components such as plant vigor, plant size, ear husk coverage, ear appearance, time interval between pollination and the appearance of the female inflorescence, contribute for a total of 52% in the variation of maize grain yield. Mali, which is located in the semi-arid zone, does not escape the holes of drought and have their direct consequences on the production of maize (Traore, 1986). However, it must be recognized that maize is nowadays an important cereal because of its high yield and its use in human and animal nutrition. This has given it a key role in food security. Considering the weather hazards that occurred during the agricultural campaigns and the poor conditions of the soils used, the improved varieties gave unsatisfactory results. However, according to the results of soil analysis, additional inputs of organic matter (PROFEBA enriched with Tilemsi Natural phosphate) would be necessary to contribute validly the management of the fertility of these soils and crop yield. Indeed, the improved genetic materials tested on On-farm were tolerant to drought and adapted to our dietary habits.

The seed cooperatives were able to produce 23,343 tons of maize seeds R1 for the benefit of the producers in the region. This reflects comments made by Tsedeke Abate, (2018) that village seeds systems are not effective in generating new maize varieties that are essential for improving productivity. But a better collaboration between community organizations involved in the production of certified seeds would probably facilitate access and availability of seeds of the genetic materials preferred by the producers.

5. Conclusion

Strengthening the resilience of the rural populations against the adverse effects of climate change necessarily involves their supply of stress-tolerant genetic materials. In the framework of the adaptation of the intermediate cycle maize varieties (110-120 days) to the agro-ecological zones of the Koulikoro region, the varieties IWDC3-SYN, PVA-SYN-22, DT-STR-SYN -2-Y, FARAKO proved to be more efficient than the SOTUBAKA, the productivity control variety for the North Sudanian zone (agricultural sectors of Kati, Kangaba, Dioila). For the maize varieties of early cycles (90-100 days), the varieties EVDT 99, DTE-STR-Y-SYN-POPC3 and POP-66-SR/ACR 91-SR showed an equal performance to BRICO, the productivity control variety for the Sahelian zone (sectors of Banamba, Koulikoro and Kolokani). These varieties would serve to increase the number of producers' choices for growing maize in the Sahelian zone of the region. The sensory analysis of the tested varieties showed that all of them were well adapted to the region's eating habits: Tô, Couscous, and Gningnin kin, considered as the main food dishes. At the end of the three years of on-farm testing, the identified maize genetic materials for strengthening the resilience of the maize producers against the adverse effects of climate change were as follows:

North Sudanian zone: Intermediate cycle maize (110-120 days), agricultural sectors of Dioila, Kati, Kangaba.

IWDC3-SYN: baptized by the producers as ***DJIGUIYA***;

PVA-SYN-22: baptized by the producers as ***DJIGUIFA;***

DT-STR-SYN-2-Y: baptized by the producers ***WASSA-KABA;***

FARACO: baptized by the producers FARAKO

Sahelian zone: Early cycle maize (90-100 days), agricultural sectors of Banamba, Kolokani, Koulikoro.

EVDT 99: baptized by the producers as ***DIAKOUMBE*****;**

DTE-STR-Y-SYN-POPC3: baptized by the producers as ***DOUSUSUMA*****;**

POP-66-SR/ACR 91-SR: baptized by the producers as ***GNATA KABA***.

The better organization and training of the village cooperatives in the community-based maize seeds production techniques would facilitate the availability of certified seeds of the maize varieties preferred by the producers. The private seed distribution network composed of the producers, seed companies and the media (local rural radio stations) would facilitate seed access to applicants and the dissemination of new varieties in the Koulikoro region.

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