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Original Research Article

Participatory Evaluation of Thirty (30) New Rice (Oryza Sativa L.) Lines Developed from Anther Culture under Senegal River Valley Growing Conditions

Ibrahima Mbodj[1*], Omar Ndaw Faye[2], Abdoulaye Fall Beye[1]

[1]Alioune DIOP University of Bambey, Higher Institute of Agricultural and Rural Training, BP 54 Bambey, Senegal
[2]Senegalese Agricultural Research Institute, Center of Saint-Louis, BP 240 Saint-Louis, Senegal

***Corresponding Author:** Ibrahima Mbodj
Alioune DIOP University of Bambey, Higher Institute of Agricultural and Rural Training, BP 54 Bambey, Senegal

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Abstract: Rice is one of the most widely used staple foods in the world. However, its production is still very limited compared to the exponentially growing demand. Senegal, with an average consumption of 90 kg/habitant, is the third largest importer of rice in Africa. Aware of the impact of imports on the population, Senegal has set itself the objective of achieving food self-sufficiency by 2022 with an average yield of 5 tonnes/ha. ISRA, through its research, contributes to the achievement of this objective by developing adapted technologies. It is within this framework that a participatory evaluation of 30 new anther culture lines was conducted at the ISRA research station in Fanaye during the hot dry season of 2020. Surveys were conducted among producers through guided tours, while observations and measurements were made to collect agro-morphological parameters and characteristics preferred by producers. The agronomic results analysed and combined with the surveys made it possible to select the 10 best performing varieties. Among these 10 best performing lines, 6 were chosen by the producers. They are KF18134, KF18040, KF18068, KF18103, KF18124, KF18048, KF18005, KF18017, KF18001, KF18024. Crop yield is the first characteristic chosen by the growers. It was followed by short cycle characteristics, panicle load, low bird damage and medium height.

Keywords: Food self-sufficiency; anthers culture, guided tour, participatory evaluation, lineage.

1. INTRODUCTION

Rice is considered to be the main source of nutritional calories for humans, and its use will reach 518.9 million tonnes worldwide in 2021 [1]. Rice is the world's third most important food grain after maize and wheat [2]. According to the latest forecasts from the International Grains Council (IGC), world rice production will increase for the sixth year running in 2021/22, reaching a new peak of 512 million tonnes, compared with an estimated 506 million tonnes for 2020/21 [3].

In Africa, rice plays a dominant role in people's diets, accounting for more than 25% of all cereals consumed, second only to maize [4]. It is in West Africa that rice has seen the greatest expansion over the last 20 years. It is grown in almost 40 of the 54 countries on the African continent, and rice growing is the main activity and source of income for more than 35 million small-scale rice farmers in Africa [4]. Local rice production covers only 60% of demand in Africa, resulting in imports of 14-15 million tonnes per year (costing over US$6 billion), which represents a considerable loss of the continent's foreign currency reserves [4].

In Senegal, rice is a staple food and the main sector, supplying 73.8% of households, but the country's needs in milled rice are estimated at around 1.5 million tonnes per year, contributing only 7.6% to the country's GDP [5]. However, 7,424,348 tonnes of white rice were produced in 2020, resulting in a deficit of around 1,070,286 tonnes, which is imported [6, 7]. Average annual rice consumption is estimated at 100 kg/capita, making it the most widely consumed cereal in Senegal [8]. Unfortunately, Senegal is 51% dependent on imports to satisfy its domestic demand for rice [5]. In order to

reduce this deficit, the Senegalese agricultural research institute (ISRA), through the Comité National des Semences et Plants, has released fifteen new rice varieties called "ISRIZ". This range of rice varieties is tolerant to abiotic and biotic stresses and meets the requirements of Senegalese consumers and producers. These new varieties have yield potential of up to 13 tonnes per hectare. To shorten the duration of varietal selection, ISRA has developed a partnership with KAFACI (Korea-Africa Food Agriculture Initiative) for the use of anther culture from the second generation, with crosses between indica and japonica subspecies. The use of Tongil-type lines derived from intraspecific crosses between japonica and indica often improves the genetic potential of rice yield, quality and taste [9].

As part of these activities, a participatory evaluation trial of 30 new rice lines developed from anther culture was carried out to (1) determine the varietal selection criteria used by growers, (2) determine the varieties most appreciated by growers, (3) study the agro-morphological parameters of the different lines and (4) select the most promising varieties for an advanced yield trial.

2. MATERIAL AND METHODS

Presentation of the site

The trial was conducted at ISRA's Fanaye experimental station in Fanaye Diéry on soil with a high clay content of between 50 and 75% (clay soil).

The geographical coordinates are: 16°31'59" North and 15°13'59" South.

Plant Material

The plant material consists of 30 lines and 5 controls. The controls are Isriz 01 (a short-cycle aromatic variety), Sahel 108 (a medium-cycle variety, the most common variety in the VFS), Isriz 06, Isriz 07 and Isriz 15 (medium-cycle varieties with good grain quality for processing and cooking). All the plant material is shown in Table 1.

Table 1: List of plant material used

Designation	Varieties N°
KF18111	1
KF18049	2
KF18104	3
KF18018	4
KF18068	5
KF18017	6
KF18102	7
KF18008	8
KF18004	9
KF18030	10
KF18124	11
KF18024	12
KF18005	13
KF18032	14
KF18015	15
KF18003	16
KF18103	17
KF18092	18
KF18040	19
KF18048	20
KF18076	21
KF18001	22
KF18013	23
KF18085	24
KF18027	25
KF18033	26
KF18007	27
KF18134	28
KF18044	29
KF18096	30
SAHEL 108	31
ISRIZ 01	32

Designation	Varieties N°
ISRIZ 06	33
ISRIZ 07	34
ISRIZ 15	35

Experimental Design: The design chosen was an alpha lattice with 3 replicates. Each replication consists of 7 blocks, each containing 5 elementary plots (Figure 1). Only one factor is studied: the lineage.

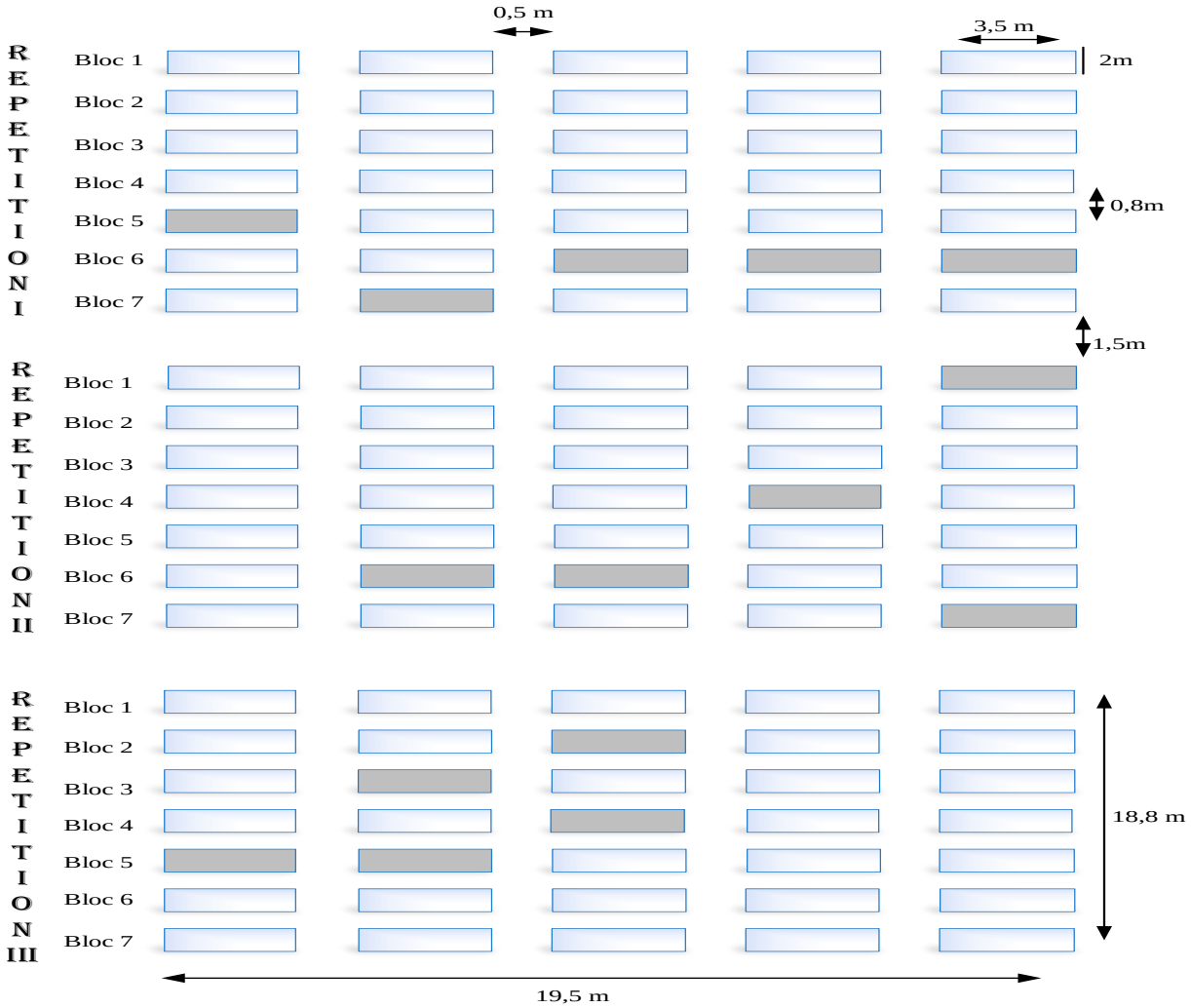

Figure 1: Diagram of the experimental set-up

Figure 1: Diagram of the experimental set-up Légende: Elementary plots of lines; Elementary control plots

Surveys of Growers:

This took place at the Fanaye experimental station when the plants had reached maturity; a group of 10 growers was selected.

Trial Management:

Ploughing followed by cross harrowing was carried out. The plot was then flooded. This loosened the soil and prevented the spread of red rice.

The paddy rice is sown in nurseries on trays.

Transplanting took place 24 days after sowing at the Fanaye experimental station. Herbicide treatment took place 26 days after transplanting. A volume of 50 ml of Calliherbe 720 SL (2,4-D Amine salts a.i.) was used, at a rate of 450

ml/ha. mixed with 400 ml of Propanil 360 EC (Propanil a.i.), giving a dose of 4 l/ha. This mixture was then diluted with 8 litres of water before being sprayed.

An additional herbicide treatment was applied on 31 DAR.

Fertilisation was carried out in 3 applications (200kg of DAP + 125kg of urea per ha, then 62.5kg of urea per ha and finally 62.5kg of urea per ha).

Gravity irrigation was used on demand.

Harvesting was carried out in 2 stages: sample harvesting and separate harvesting of the edges and centres of the elementary plots.

Measurements and Observations: Measurements and observations were carried out at various stages of plant development. Several parameters were measured.

During Vegetation

- Number of tillers per plant: in each plot, 4 clusters were selected at random in the area and the number of tillers was counted.
- Heading start date: This is the date on which the first ear of corn appears on one of the plants in the plot.
- Date flowering begins: this is obtained by observing the appearance of the first flower on the plot.
- Date 50% flowering: this corresponds to the date on which 50% of the plants in an elementary plot have flowered.
- 80% heading date: this is the date on which 80% of the plants on the elementary plot have headed.

At maturity:

- Date 80% ripe: this is when 80% of the plants observed have reached maturity.
- Plant height: measured with a ruler. Measurements are taken from the collar to the highest point on the plant, which may be the panicle.

Yield Components

- The average weight of a panicle: this is calculated on the average of 10 panicles weighed using the "Nimbus" hypersensitive electronic blank;
- The average length of a panicle: this is calculated from the average of 10 panicles measured using a graduated ruler;
- The average number of empty grains in a panicle: the panicles are dehulled and the number of empty grains is counted for each panicle. The average is then calculated for the 10 panicles;
- Average number of filled grains per panicle: this is calculated from the average number of filled grains counted for each panicle;
- Average number of total grains per panicle: this is calculated by adding the number of empty grains and the number of filled grains;
- Weight of 1000 grains: 1000 filled grains are counted and then weighed using electronic scales.
- The moisture content of the rice grains: this is measured using a device called a moisture meter.
- Percentage of sterility: this is obtained by multiplying the number of empty grains by 100.

$$\% \text{ stérility} = \frac{\text{Number of empty grains}}{\text{total number of grains}} \text{ X } 100$$

Average weight per bunch: this is obtained by dehulling all the panicles in a bunch and weighing them using an electronic balance. Yield evaluation:

The yield is obtained by multiplying the average weight of the grains per bunch, adjusted to 14% moisture, by the number of plants obtained per hectare (ha) using the 20 cm X 20 cm spacing, which was used for the trial. The number of plants is 25,000 plants per hectare. To adjust the average weight per bunch to 14% moisture, the following formula is used:

$$\text{Pack weight adjusted to 14\%} = \frac{100 - \text{Humidity reading}}{100\text{-}14} \text{ X average weight per pocket}$$

Data Processing:

- Data processing was carried out using Excel 2016 to enter data and draw up tables.
- Data analysis was carried out using BREDING VIEWS software.

2. RÉSULTS

Producer Surveys: The analysis of the results mainly concerns the varieties chosen and the criteria used by growers.

Varieties Chosen by Growers

Analysis of the diagram showing the choice of growers according to the scores given (Figure 2) shows that 14 of the 30 lines were chosen. The lines were chosen in comparison with the controls. Almost all the lines chosen were judged to be very good compared with the controls. Only line KF18008 was judged comparable to the control and was chosen only once among the 8 producers. However, KF18008 is the most selected line, followed respectively by KF 18017, KF 18068, KF 18048 and KF 18015.

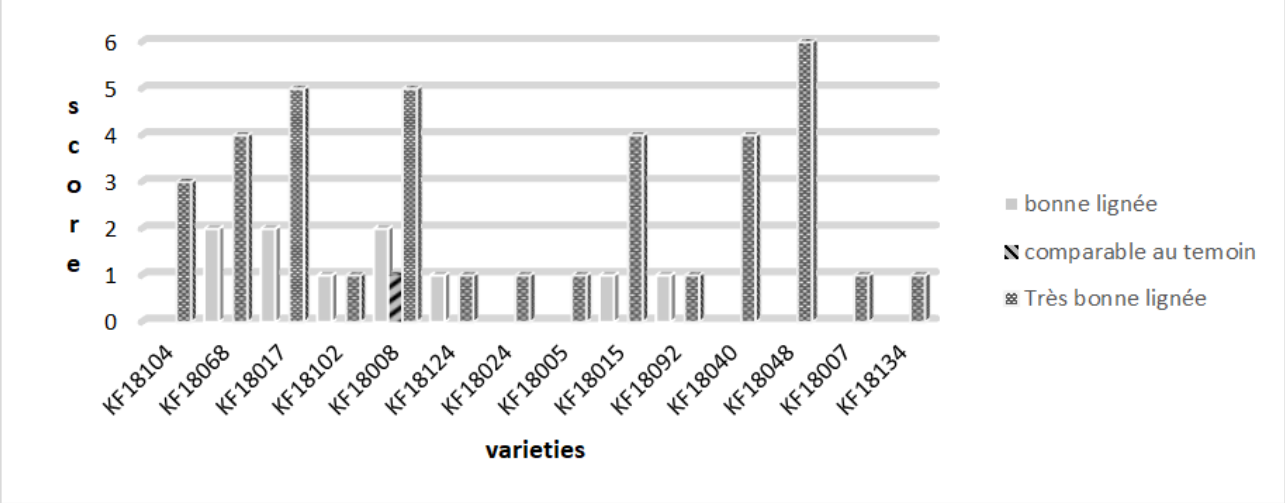

Figure 2: Diagram of varieties chosen according to scores

The table below summarises the top three choices made by producers.

Table 1: Lines most chosen by growers

N°	Varieties	Rank	Reasons
8	KF18008	1	Short cycle, resistant to lodging, medium height, good yield, low ginning on the plot, long panicle, good grain filling.
6	KF18017	2	Good yield, low ginning on the plot, short cycle, long panicle, good heat load, lodging resistance, uniformity of maturity, low bird damage.
5	KF18068	3	Good yield, short cycle, resistance to lodging, low bird damage, long panicle, well filled panicle, low bird damage, uniformity of maturity, average height, good tillering.

Producer selection criteria:

Analysis of the growers' choice diagram (Figure 3) shows that growers focus on 15 characteristics when choosing varieties. Crop yield is the first characteristic used by growers. This was followed by short cycle, panicle load, low bird damage and average height. However, flavour and grain quality were the characteristics least used by growers

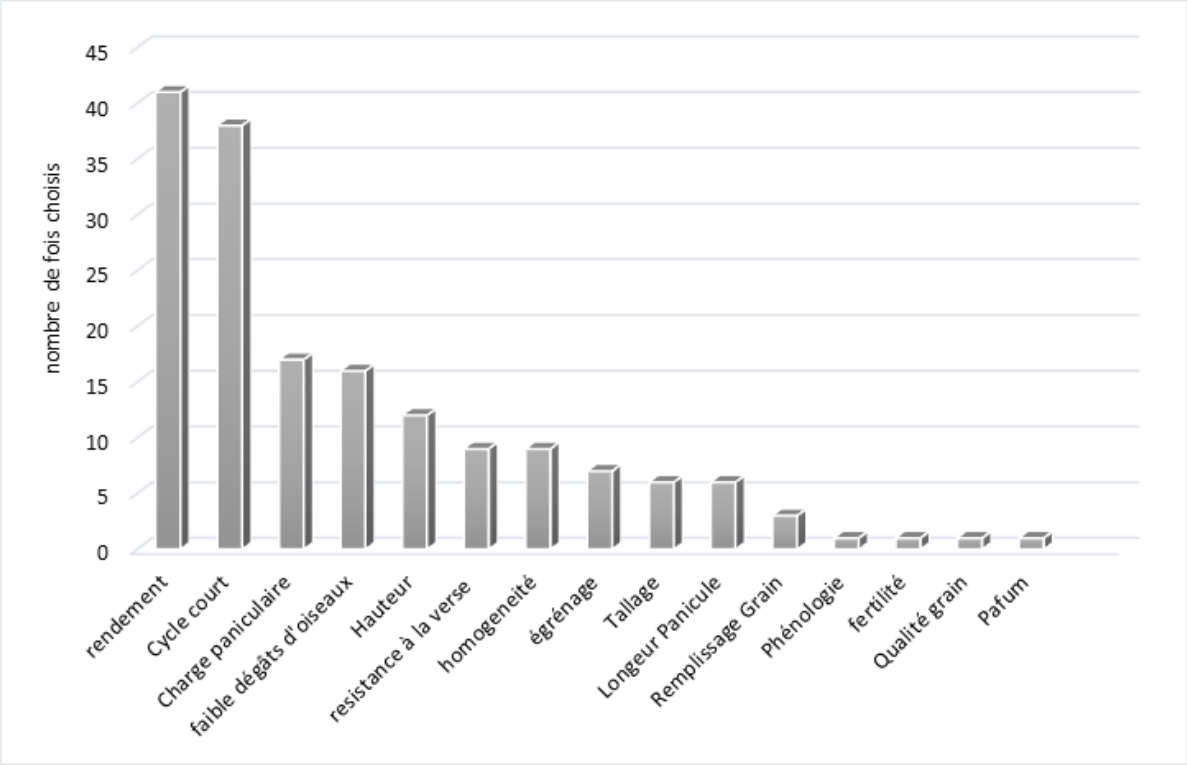

Figure 3: Diagram of producer choice characteristics

Agro-Morphological Parameters

All the data collected are recorded in the agro-morphological parameters table (Table 3).

Table 3: Results of agro-morphological parameters

Geno type		**Cycle semis-épiaison (j)**	**sowing-50% flowering (j)**	**sowing to 80% heading (j)**	***talle number***	***height* (cm)**	***panicle weights*(g)**	***panicle length*(cm)**	**PMG (g)**	**Rdt T/ha**	**%_ stérility**
Controls	SAHEL 108(bis)	92,51	104,88	137,3	28,26	108,89	3,47	26,33	24,21	9,52	43,27
	ISRIZ 07	94,8	105,33	138,67	27,11	80,59	2,4	21,63	24,23	9,131	43,11
	ISRIZ 06	92,91	105,03	136,1	21,21	87,3	2,4	27,13	17,57	9,01	36,39
	ISRIZ 15	101,66	107,09	140,81	18,22	114,73	3,01	26,18	23,86	7,97	52,75
	ISRIZ 01	86,77	104,15	133,22	13,68	79,52	1,77	19,04	28,7	4,56	38,74
lines tested	Min	86,77	104,15	133,22	13,68	79,52	1,77	19,04	17,57	4,56	36,39
	Max	101,66	107,09	140,81	28,26	114,73	3,47	27,13	28,7	9,53	52,75
	Moy	93,73	105,296	137,22	21,696	94,206	2,61	24,062	23,714	8,04	42,85
	Mean LSD	7,9	17,82	9,06	8,14	15,2	5,45	3,42	8,31	4,86	45,53
	p-value	0	0,33	0,02	0,09	0	0,62	0	0,02	0,12	0,9

Seed-to-seed cycle

Cycle length varied between 87 and 108 days (Figure 4). The best control is the ISRIZ 01 variety with a cycle length of 87 days. It also had the shortest cycle length.

The analysis of variance between the different varieties tested showed a significant effect at the 5% threshold (p-value =0.0002).

The test of the smallest significant difference PPDS of the different averages showed that the varieties KF18049, KF18111, KF18134, KF18076, KF18013, KF18040, KF 18048, KF18001 and KF18004 are similar to the best control.

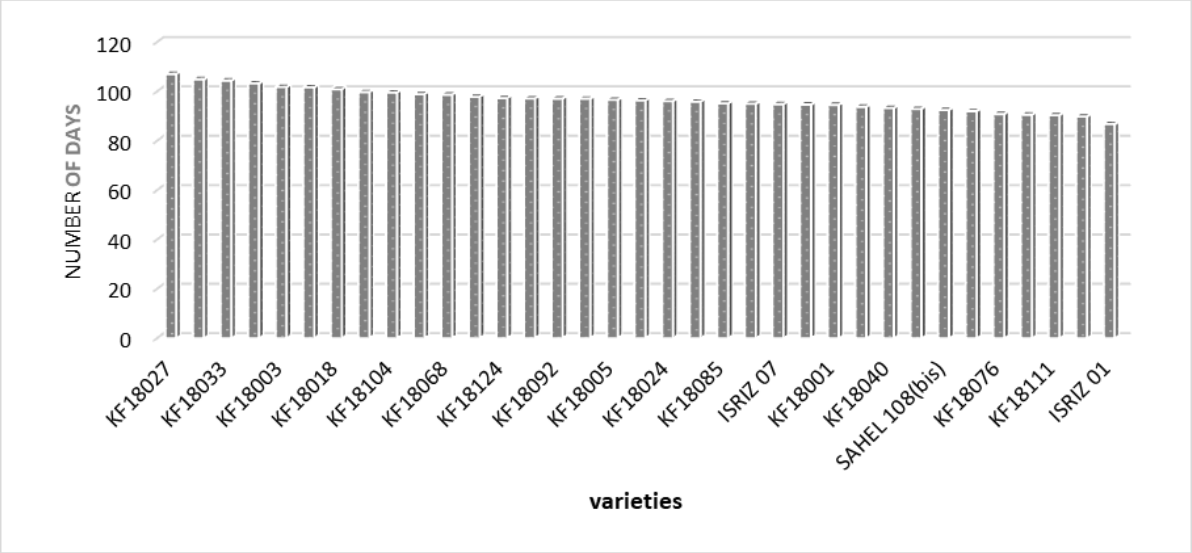

Figure 4: Diagram of the length of the sowing-epiposition cycle

Sowing-Flowering Cycle:

The duration of the sowing-50% flowering cycle varied from 104 to 107 days (Figure 5). The best control was the ISRIZ 01 variety with 104 days. The longest duration was recorded by the ISRIZ 15 variety.

Analysis of variance showed that there was no significant effect between the varieties tested, at the 5% threshold (P-value = 0.331). All the lines are therefore identical to the best control.

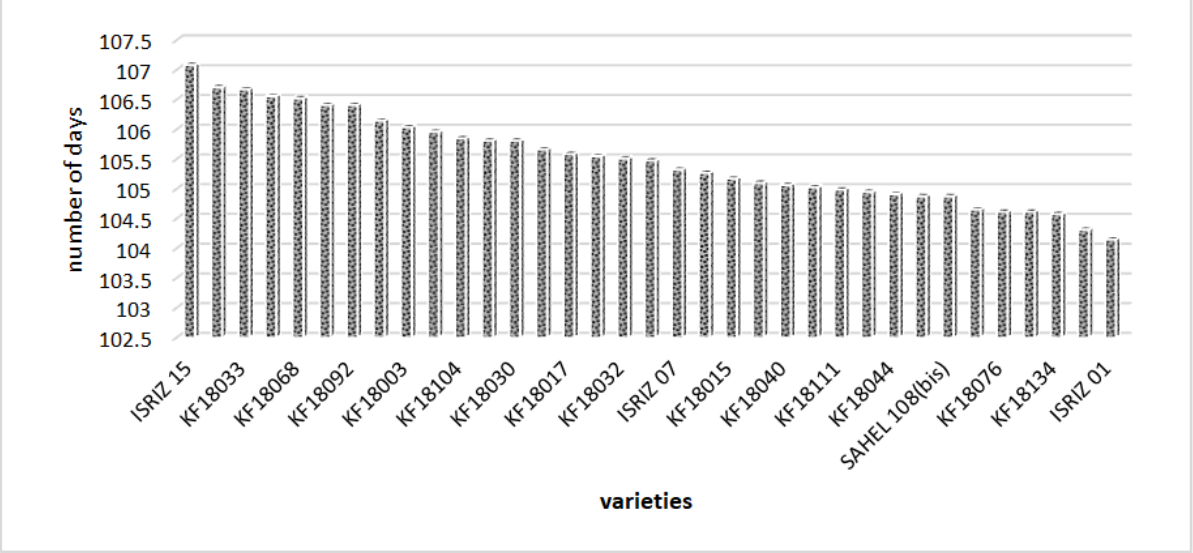

Figure 5: Diagram of the duration of the sowing-50% flowering cycle

Sowing cycle-80% maturity

The duration of the sowing-80% maturity cycle varied from 133 to 143 days (Figure 6). The best control was ISRIZ 01 with 133 days. The longest duration was recorded by the KF18027 variety.

The analysis of variance showed a significant difference between the different varieties tested at the 5% threshold (p-value = 0.019).

The PPDS test showed that the best control (Isriz 01) was superior to all the lines in terms of earliness.

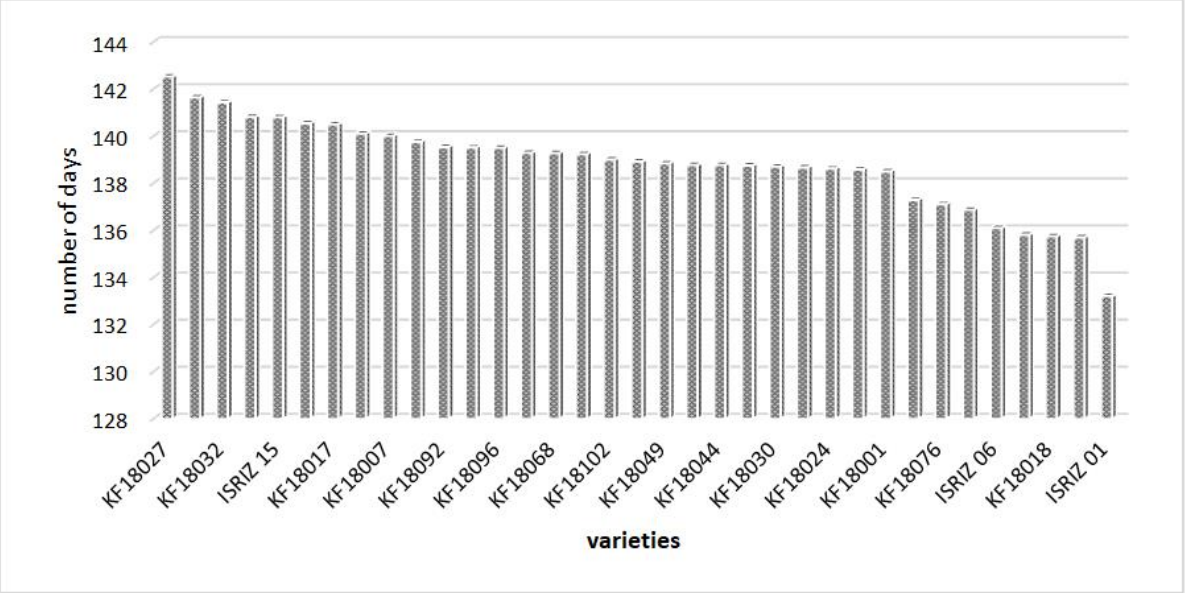

Figure 6: Diagram of the duration of the cycle from sowing to 80% heading

Talle number

The average number of tillers varied from 14 to 29 (Figure 7). The variety Sahel 108 was the best control with 28 tillers. The highest number of tillers was recorded by line KF18044 with 29 tillers, followed by KF18134 with 28 tillers.

Analysis of variance showed that there was no significant difference between the varieties tested at the 5% threshold (p-value= 0.09).

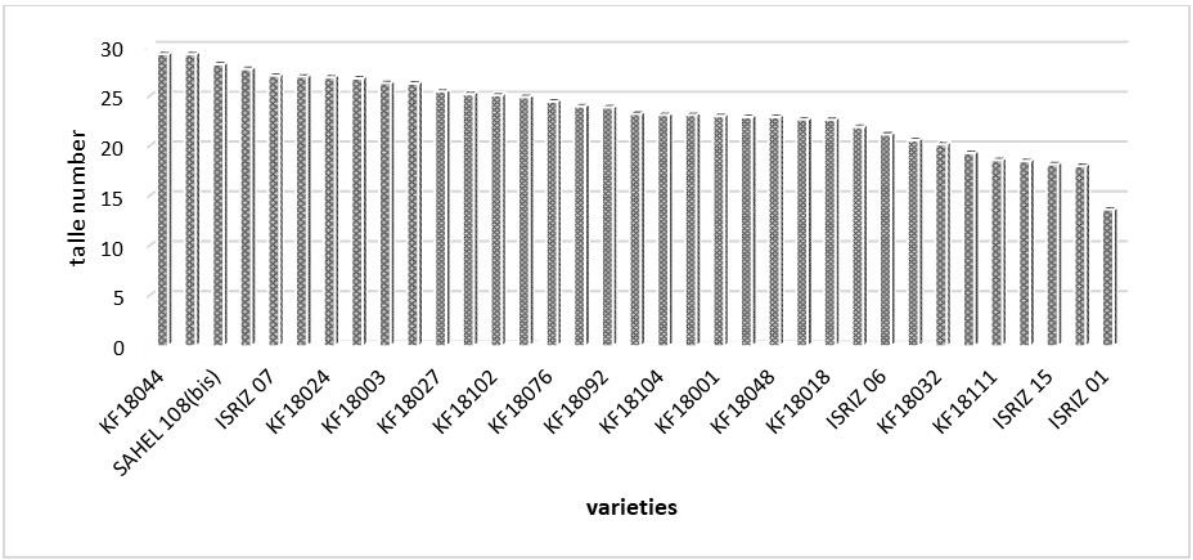

Figure 7: Talle number diagram

Height of plants

Plant heights varied on average between 79 cm and 144.48 cm (Figure 8). The ISRIZ 15 variety was the best control at 99.53 cm. However, KF18096 recorded the highest height at 144.48 cm and ISRIZ 06 the lowest.

The analysis of variance shows that there is a highly significant difference between the different varieties tested at the 1% threshold (p-value = 3.1e-11).

The PPDS test of height means showed that the varieties KF18096, KF18111, KF18134 are similar to the best control.

The analysis of variance shows that there is a highly significant difference between the different varieties tested at the 1% threshold (p-value = 3.1e-11).

The PPDS test of height means showed that the varieties KF18096, KF18111, KF18134 are similar to the best control.

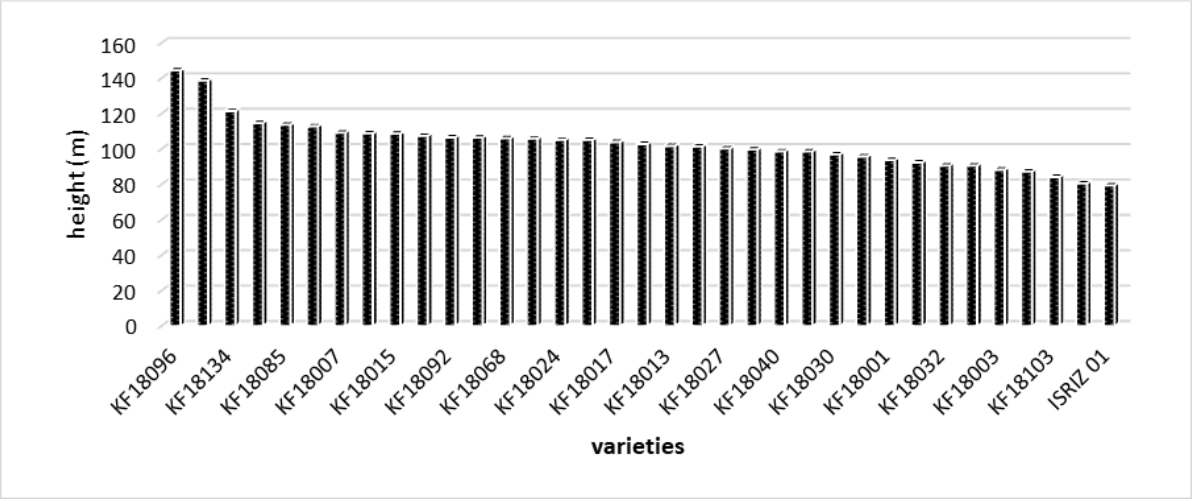

Figure 8: Average height diagram

Average panicle weight

The average weight per panicle varied from 4.01 to 1.61 (Figure 9). The best control was the Sahel 108 variety. However, the highest average weight was obtained by the variety KF18048.

Analysis of variance showed that there was no significant difference between the varieties tested at the 5% threshold.

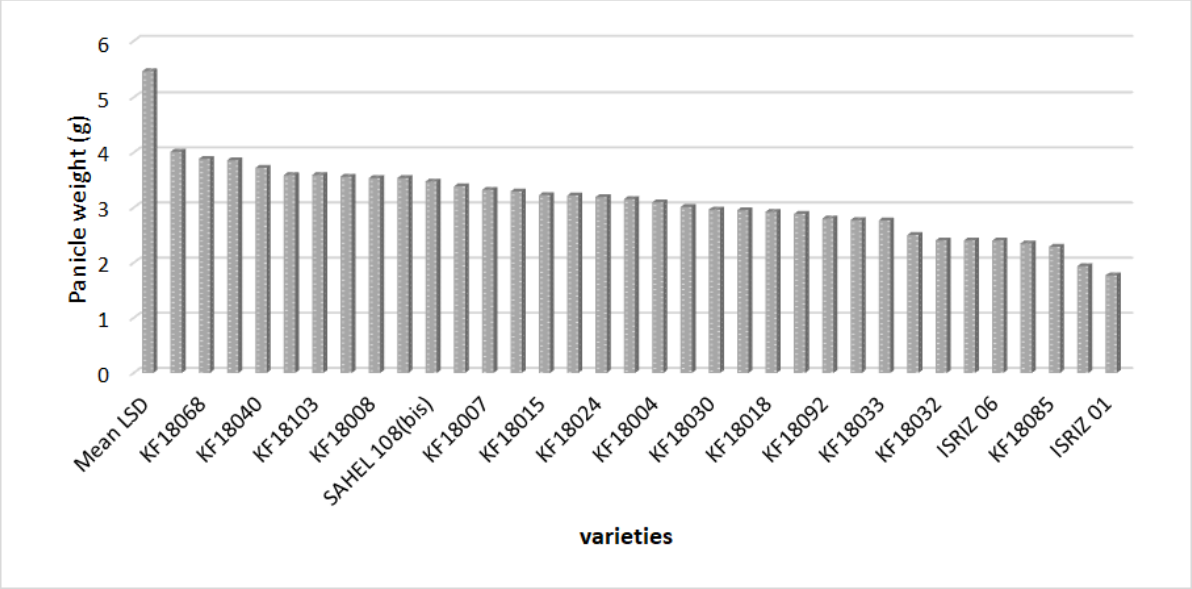

Figure 9: Diagram of average panicle weights

Average length of panicles

The average length of the panicles varied from 15.63 cm to 23.72 cm (Figure 10). ISRIZ 06 was the variety with the longest average panicle length and was also the best control. It was followed by Sahel 108 and ISRIZ 15, with 26.33 cm and 26.18 cm respectively.

The analysis of variance showed that there was a significant difference between the average panicle lengths at the 5% threshold.

The PPDS test carried out on the average panicle lengths showed that the varieties KF18096, KF18007, KF18005, KF18134, KF18008, KF18015, KF18124 are similar to the best control.

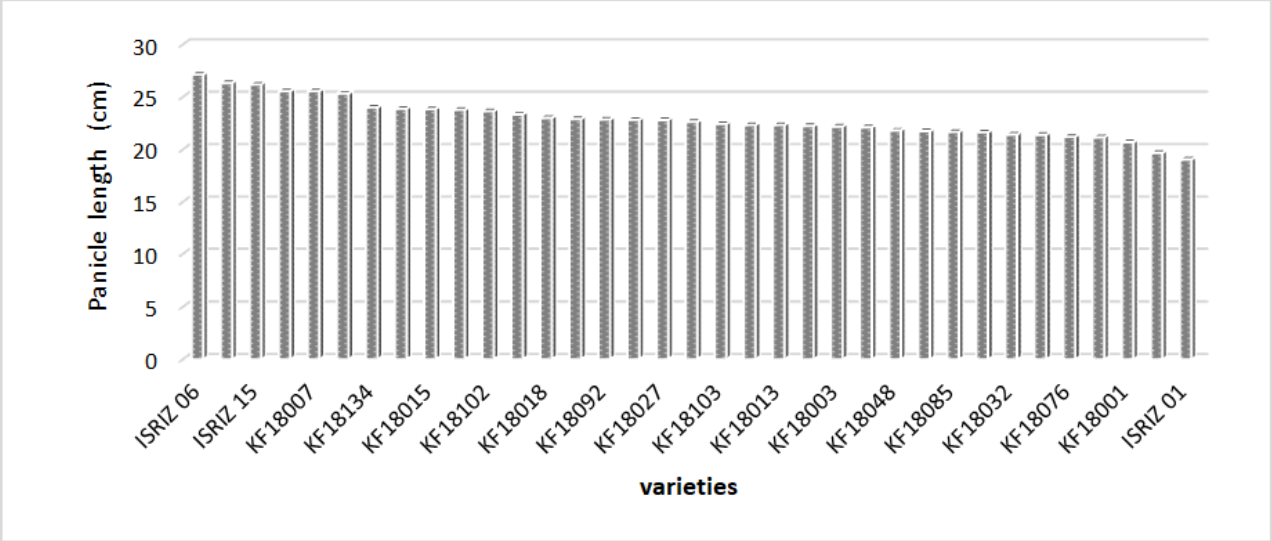

Figure 1: Diagram of average panicle length

Weight Thousand grains (PMG)

The average weight of 1000 seeds varied from 31.80 g to 13.20 g (Figure 11). The best control was the ISRIZ 01 variety, with an average weight of 28.70 g. However, the highest MPG was recorded by the KF18024 variety, followed by the ISRIZ 01 variety.

The analysis of variance showed that there was no significant difference between the average weight of the GMP between the different varieties tested at the 5% threshold (p-value = 0.015).

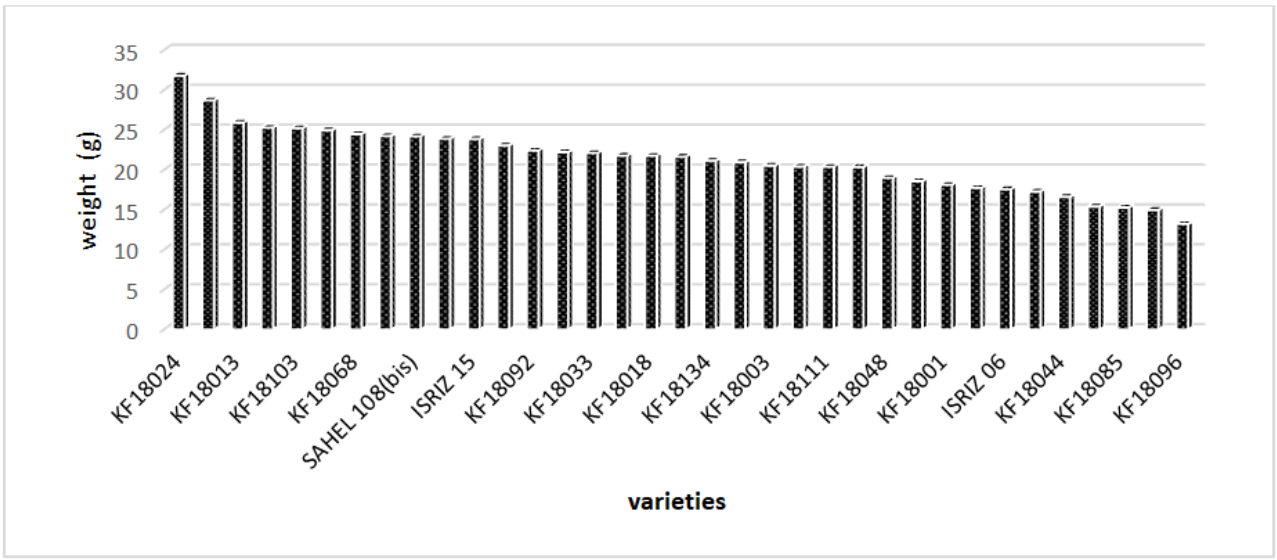

Figure 2: Diagram of average PMG

Yield

Yields ranged from 4215.42 kg/ha to 13005.41 kg/ha (Figure 12). The best control was the Sahel 108 variety with 9527.92 kg/ha. However, the best yield was recorded by the variety KF18134 (13005.414 kg/ha), followed respectively by KF18040 (12148.501 kg/ha), KF18068 (11852.001 kg/ha), KF18103 (11643.41 kg/ha) and KF18124 (11144.08 kg/ha). Analysis of the variance between average yields showed that there was no significant difference between the different varieties tested at the 5% threshold (p-value = 0.120).

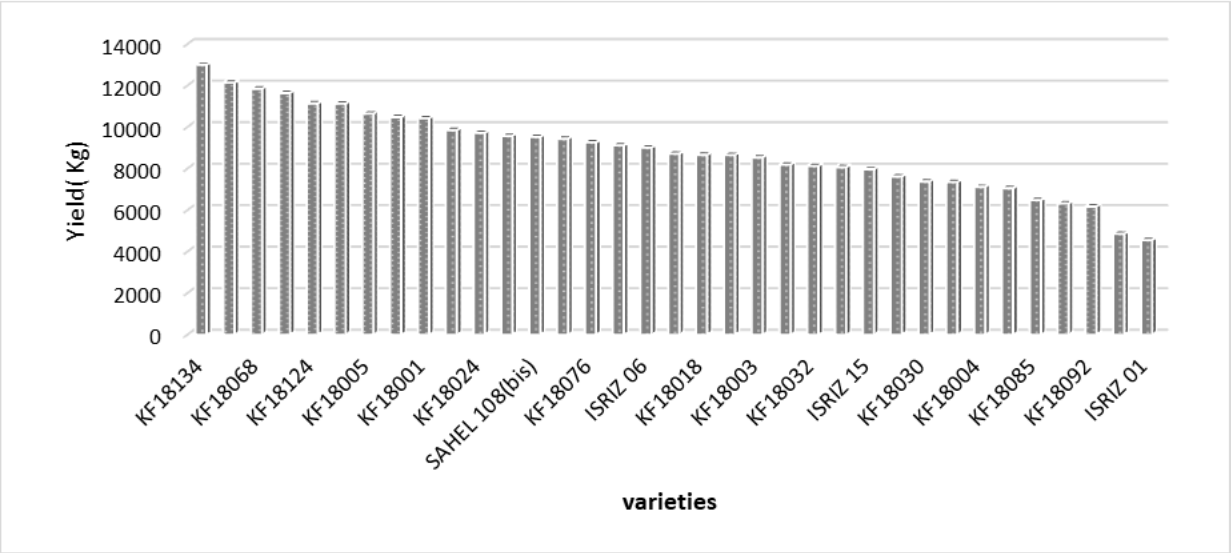

Figure 3: Yield diagram

Sterility rate

The sterility rate varied from 19.24% to 76.89% (Figure 13). ISRIZ 06 was the best control with a sterility rate of 36.39%. KF18049 had the highest sterility rate, while KF18008 had the lowest.

The analysis of variance showed that there was a highly significant difference at the 1% threshold between the different varieties tested (p-value = 1.14e-07).

The PPDS sterility rate test showed that the varieties KF18027, KF18048, KF180032, KF18030, KF18103, KF18018 and KF 18027 were similar to the best control.

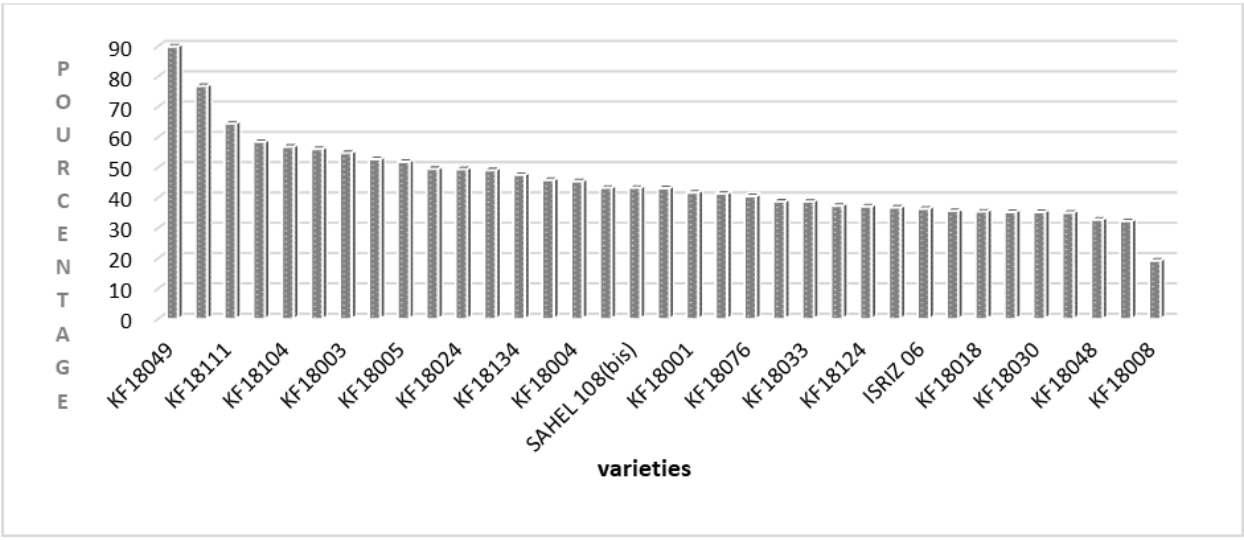

Figure 4: Sterility rate diagram

3. DISCUSSION

Guided visit

A guided tour enabled producers to choose the best lines and give their reasons for doing so. The 5 best lines chosen were : KF 18008, KF 18017, KF 18068, KF 18048 and KF 18015. The criteria used to select these lines were mainly crop yield, earliness, panicle load, low bird damage and height (Table 2). These criteria are in line with those of [10, 11].

All the selected criteria are intrinsically linked to yield increase. This can be explained by the fact that the farmer seeks to obtain the maximum possible yield. However, the criterion of earliness is linked to the possibility of double cropping, avoiding the stubble of the two seasons, which is the main constraint.

Agronomic Parameters:

Experimentation at the Fanaye station has enabled us to obtain a series of results. This should lead us to select the 10 best lines for the VFS growing conditions.

The overall length of the sowing-epiposition cycle of the varieties could be due to the impact of the cold on the seedling stage. The reproductive phase is relatively fixed. However, the growth phase is influenced by low temperatures and the photoperiod (day length), which can, when the variety is sensitive, lengthen its duration [12].

For the sowing-80% maturity cycle, there was a significant effect at the 5% level (p-value = 0.019). The controls for the counter-hot season (CHS) had a longer cycle than the technical data sheet. We recorded 33 days for Isriz 01, 16 days for Isriz 06, 15 days for Isriz 07 and 20 days for Isriz 15.

Changes in the average number of tillers per plant had no significant effect at the 5% threshold (p-value=0.09). Nevertheless, it can be noted that the lines KF18044 (29 tillers), KF18134 (29 tillers), KF18008 (28 tillers), KF18103 (27 tillers), KF18024 (27 tillers), KF18096 (27 tillers), KF18003 (26 tillers), KF18124 (26 tillers) and KF18027 (26 tillers) as well as the varieties Sahel 108 (28 tillers) and ISRIZ 07 (27 tillers) recorded high tillering. Tallage is said to be high when the number of tillers exceeds 25 [13].

With regard to height, there was a highly significant difference at the 1% threshold between the different varieties tested (p-value = 3.1e-11). The PPDS test of height means showed that the varieties KF18096, KF18111, KF18134 are similar to the best control. All other lines are lower than the best control.

The average variation in yield had no significant effect at the 5% threshold (p-value = 0.120). However, the best yield was recorded by the variety KF18134 (13005.414 kg/ha), followed respectively by KF18040 (12148.501 kg/ha), KF18068 (11852.001 kg/ha), KF18103 (11643.41 kg/ha) and KF18124 (11144.08 kg/a). Line KF 18111 was unable to confirm its performance in the preliminary yield trial (OYT), where it had the highest yield at 11054 kg/ha [14]. This difference could be explained by the fact that birds caused severe damage to line KF18111 during the trial. On the other hand, the yields obtained were generally higher than those obtained in the 2019 multi-environment trial [14]. This can be explained by the fact that these trials were conducted in farmers' environments, unlike this one, which was conducted on an experimental station.

Combination of Choice of Producers and Statistical Results

The growers used a set of criteria for their choice of lines. However, only 3 of these criteria were analysed statistically. These were: yield, tillering and height. The work of [10] shows that there is a good correlation between yield and the number of tillers.

Line KF18134 stood out from the other varieties chosen by growers because it recorded both the best yield and the best tillering. Similarly, KF18024 recorded a good yield and high tillering. In addition, lines KF18040 and KF18068 successively recorded the 2nd and 3rd best yields with good tillering (successively 21 and 22). According to [13], tillering is said to be good when it is between 20 and 25. Finally, the most popular lines were KF18008 and KF18017. However, KF18008 recorded a lower yield than the best control with a high tillering. Line KF18017 recorded a higher yield than the best control with average tillering. According to [13], tillering is said to be average when it is between 15 and 20.

In the end, the 10 best-performing lines were chosen for the advanced yield test (PAT), 6 of which were chosen by the growers (Table 3).

Table 2: Lines selected for the advanced yield test

Varieties	Chosen by producers
KF18134	yes
KF18040	Yes
KF18068	yes
KF18103	No
KF18124	yes
KF18048	No
KF18005	No
KF18017	Oui
KF18001	Non
KF18024	Oui

4. CONCLUSION

This study was carried out with a view to expanding the varietal map with varieties that will be adopted by growers. It enabled us to evaluate, in a participatory way, the 30 new lines resulting from anther culture under VFS growing conditions. The surveys carried out, through a guided tour of the growers, enabled us to find out their main criteria for choosing the growers' varieties. These are yield and earliness. Similarly, statistical results on agro-morphological parameters enabled us to identify the 10 most promising lines from an agronomic point of view. However, the combination of these 2 results enabled us to select the 10 best lines, meeting the growers' requirements. These lines are: KF18134, KF18040, KF18068, KF18103, KF18124, KF18048, KF18005, KF18017, KF18001 and KF18024. These are the lines chosen for the advanced yield test.

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