Vol. 18(11), pp. 933-945, November, 2022
DOI: 10.5897/AJAR2022.16111
Article Number: 72FD8A469887
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Study of the combined effect of sowing date and sowing method on vegetative development of new rice paddy (*Oryza sativa*) varieties in Senegal River Valley under low temperatures

Koffi Marchais KITTIKA[1,2*], Omar Ndaw FAYE[2] and Anicet Georges Bruno MANGA[1]

[1]UFR Sciences Agronomiques d'Aquaculture et des Technologies Alimentaires, Université Gaston Berger de Saint-Louis, Saint-Louis, Senegal.
[2]Centre de Recherches Agricoles de Saint-Louis de l'Institut Sénégalais de Recherches Agricoles (CRA/ISRA/SL), Saint-Louis, Senegal.

Received 13 June, 2022; Accepted 9 August, 2022

Rice paddy cultivation in Senegal is subject to climatic fluctuations that affect its vegetative development. Although climatic conditions are a concern, we hypothesized that the new rice paddy ISRIZ would be better adapted to these fluctuations and would allow double cropping. We studied the vegetative behavior according to the date and mode sowing under low temperatures. An experiment was carried out in a split-split plot design with sowings staggered every three weeks (18 dates), and two sowing modes (Broadcast, transplanting). Data collected included plant height, number of tillers, 50% flowering, 80% maturity. The results showed that the sowing date and method had significant effects on the morphology of the varieties. These effects were exacerbated by low temperatures, resulting in a lengthening of the cycle of the varieties. Some varieties performed well with flowering cycles of less than 100 days and are adapted to double cropping. The best planting period during the hot dry season is between February and March, while in winter, planting between July and August is recommended. In the cold, the practice of transplanting is better adapted. This study identified new varieties that could be adapted to the practice of double cropping in a context of climatic variability.

Key words: Irrigated rice, sowing dates, low temperatures, double cropping.

INTRODUCTION

In West Africa, many farmers face unpredictable yields due to various constraints, including climatic hazards. This leads to lower incomes and increased food insecurity in the region. In addition, climate change will pose enormous challenges to food security (Johnson and Brown, 2014; Waongo et al., 2015). One of the crops

*Corresponding author. E-mail: marchais1991@gmail.com.

facing the challenges of climate change is rice production, which has become a staple food and a strategic commodity for much of the world's population (Fall, 2007; Matlon et al., 2011). Rice is one of the most important cereal crops, and maintaining high and stable rice production is an important prerequisite for ensuring food security (Guo et al., 2020; Wang et al., 2021; Xu et al., 2016). Rice, being a thermophile plant, finds optimal condition for photosynthesis at temperatures of 25 to 35°C (var. *indica*) or 20 to 33°C (var. *japonica*) (Yoshida, 1981). Although it can adapt to a wide range of temperatures, depending on the variety, rice is sensitive to temperature peaks (low and high) at certain stages of its phenology. The growth and development process of rice are susceptible to temperature changes, especially a decrease in temperature (Ohno et al., 2018; Wang et al., 2021). This often requires a precise choice of varieties to be planted according to the growing season. Several studies have shown that the microspore stage is very sensitive to low temperatures, which inhibit microspore development, modify the anther proteome and lead to spikelet sterility (Godwin et al., 1994; Imin et al., 2006; Mamun et al., 2006). In Senegal, rice is grown intensively in the Senegal River Valley. In order to increase yields, double cropping is practised, mainly in irrigated mode. However, in recent years, the success of double cropping has become increasingly difficult due to factors such as climate, technical itineraries and pest pressure (Sie, 1997). Indeed, the main rice paddy season takes place during the hot dry season from mid-February to mid-March. The area planted during the winter season (from the end of July to the end of August) is constantly decreasing due to various constraints, including climatic hazards. As a result, the choice of varieties and sowing date are necessary elements inherent to good rice productivity. In order to cope with the drop in yields, eight new ISRIZ varieties released by the Agricultural Research Centre of Saint-Louis, Senegal and being disseminated in the Senegal River Valley have been developed. However, no studies have been conducted on their vegetative behaviour in relation to possible environmental changes. Thus, the objective of this study was to determine which of the new varieties are likely to have good vegetative behaviour in relation to sowing date and method. This research study could help to better adapt rice paddy production in the Senegal River Valley to climate change.

MATERIALS AND METHODS

Location and climatic conditions of the study site

The experiment was carried out at the Experimental Station of the *Centre de Recherches Agricoles* of the Senegalese Institute of Agricultural Research in Fanaye, Senegal (16°33N and 15°46W). The climate of the site is characterised by a rainy season with an average of 200 mm of rainfall per year from July to October, a cold dry season from November to February and a dry season from March to June (Haefele et al., 2004).

Plant

The planting material is composed of twelve (12) varieties of various origins (Table 1). Four released varieties (Nerica_S_44; Sahel 108; Sahel 177 and Sahel 201), which account for more than 95% of the area planted in valley, were chosen as controls because of their good adaptation to the climatic conditions of the Senegal River Valley (SRV).

Experimental design

A split-split plot design was used. The factors studied were the variety (twelve), the sowing method (with two modalities: direct broadcast sowing and sowing in a nursery followed by transplanting), and the sowing date (with thirteen modalities: sowing every 21 days). Table 2 summaries the different sowing dates.

Crop management

Soil preparation

The soil was worked after pre-irrigation by means of double pass offset discs, about 10-15 cm (uniform) deep, and mechanical levelling. This was essential for water management, weed control and good distribution of fertilisers.

Pre-sprouting: Pre-germination was done in two (soaking and incubation) to trigger the germination process (Table 2)**.** Soaking consisted of soaking the seed in a cloth bag with water for 24 h in a container. This allowed the seeds to absorb the necessary amount of water to trigger germination. Incubation consisted of placing the seed bags after 24 h of soaking in a well-ventilated place at a temperature of about 30°C for 24 h until germination. At the end of this time, the seeds germinated well. From November onwards, when the cold weather started to set in, the incubation period was extended from 24 to 48 h.

Sowing method: In direct sowing, the quantity of seed used was 80 kg/ha, that is, 40 g of seed per 5 m^2 (5 m×1 m) elementary plot. In nursery sowing, the quantity of seed used is 40 kg/ha, that 20 g of seed sown in trays. Transplanting was done twenty-one days in the nursery on 5 m^2 (5 m×1 m) elementary plots with spacing of 20 cm by 20 cm.

Fertilisation of experimental plots: NPK nutrient requirements, estimated at 120-60-60 per unit were applied, DAP (18-46-00) as a basal fertiliser and urea (46-00-00) as a cover fertiliser. Urea was applied in two fractions, 50% at the beginning of tillering and 50% at panicle initiation and potassium K (60 kg/ha) in the form of KCl.

Water management in the plots: Rice needs an appropriate amount of water for the different phases of the plant's development. For both sowing methods, the plots were sown and transplanted respectively under a 5 cm water depth. This water depth was maintained for one week. The plots were then drained and left dry for three days before being irrigated again at a 5 cm water level

Table 1. Characteristics of the rice paddy varieties tested.

Variety	Cycle to maturity (days)		Yield ($kg.ha^{-1}$)		Others traits
	CSC	HIV	Potentials	Field	
Isriz 01	100	88	12500	8500	Cold and salt tolerance
Isriz 02	110	90	1200	8500	Cold tolerance
Isriz 03	120	92	13500	8600	Cold and salt tolerance
Isriz 04	125	105	13500	8500	Cold tolerance
Isriz 05	125	104	13500	87200	Cold tolerance
Isriz 06	120	103	13500	7224	Cold tolerance
Isriz 07	123	106	12500	7500	Cold tolerance
Isriz 12	127	106	12000	8000	Cold, water deficit tolerance
Nerica_S_44	122	110	12000	8000	Short cycle
Sahel 108	117	105	10000	7000	Short cycle, grown in the CSC
Sahel 177	122	112	10000	7000	Aromatic, grown in CSC
Sahel 201	142	121	10000	6000	Medium cycle

CSC: Counter hot season; HIV: winter season.
Source: Faye and Fall (2018)

Table 2. The different sowing dates from D1 to D18.

Date	Tramping	Incubation	Broadcast	Transplanting
D1	02/01/2017	03/01/2017	05/01/2017	26/01/2017
D2	23/01/2017	24/01/2017	26/01/2017	16/02/2017
D3	13/02/2017	14/02/2017	16/02/2017	09/03/2017
D4	06/03/2017	07/03/2017	09/03/2017	30/03/2017
D5	27/03/2017	28/03/2017	30/03/2017	20/04/2017
D6*	18/04/2017	19/04/2017	20/04/2017	11/05/2017
D7*	09/05/2017	10/05/2017	11/05/2017	01/06/2017
D8*	30/05/2017	31/05/2017	01/06/2017	22/06/2017
D9*	20/06/2017	21/06/2017	22/06/2017	13/07/2017
D10*	11/07/2017	12/07/2017	13/07/2017	03/08/2017
D11	01/08/2017	02/08/2017	03/08/2017	24/08/2017
D12	22/08/2017	23/08/2017	24/08/2017	14/09/2017
D13	12/09/2017	13/09/2017	14/09/2017	05/10/2017
D14	03/11/2017	04/10/2017	05/10/2017	26/10/2017
D15	24/10/2017	25/10/2017	26/10/2017	16/11/2017
D16	13/11/2017	14/11/2017	16/11/2017	07/12/2017
D17	04/12/2017	05/12/2017	07/12/2017	28/12/2017
D18	25/12/2017	26/12/2017	28/12/2017	18/01/2018

*Data for sowing dates D6 to D10 were not analysed due to unavailability of data for these sowing dates.
Source: Authors

until the third week after direct sowing and transplanting. Again the plots were drained and left dry for two days to apply the herbicide (Propanyl and Weedon (2-4-D)). A new irrigation was carried out and kept at 3 cm for five days for the application of the first fertilizer. The irrigation water was raised to 5 cm until panicle initiation (IP), which marks the beginning of the reproductive phase. For the second fertilizer application, the water level was lowered to 3 cm for five days and then raised to 10-15 cm water level until the doughy grain stage. Finally, from the beginning of repining, the plots were drained until they were completely dry at maturity.

Measured parameters

The temperature data were collected at the Fanaye weather station during the whole experimentation period. The agro-morphological parameters monitored were:

(1) The average height of the plants (HAUT).

$$HAUT = \frac{sum\ of\ the\ heights\ of\ 5\ plants}{5}$$

(2) Average number of tillers per plant (TALL):

(a) In transplanting mode.

$$TALL = \frac{sum\ of\ the\ tillers\ on\ 5\ poquets}{area\ of\ the\ 5\ poquets}$$

(b) In direct seeding mode, we counted the number of tillers per meter square

(3) Days of 50% flowering 50% FLO: The date at which 50% of the plants in the elementary plot have reached was noted.

50% FLO = Difference between sowing date and 50% flowering date

(4) Days of 80% maturity 80% MAT: The date at which 80% of the plants in the elementary plot have reached maturity was noted.

80% MAT = Difference between sowing date and 80% maturity date

Data processing and analysis

The analysis of variance carried out the different factors (sowing date, sowing method and variety) and interaction of these factors on the parameters studied. Statistical analyses were performed on the variables studied using GenStat Discorvery Edition 4 software. All analyses were performed at the 5% level and in case of significant differences; multiple comparisons of means were performed using the Tukey test (Tukey, 1949). The R software allowed us to perform the principal component analysis and the hierarchical ascending classification.

RESULTS AND DISCUSSION

Temperature development during the test period

Minimum temperatures ranged from 12.39 to 22.86°C from January 2017 to April 2018 (Figure 1). The lowest temperatures were recorded in December-January 2017. The same trend was observed in 2018. From February onwards, a gradual increase in temperature was noted, with a peak between June and August 2017 (24 and 26°C), before decreasing to 12.39°C in January 2018. The maximum temperature varied between 28.75 and 38.79°C with peaks between June and October (36 and 38.79°C). Finally, the average temperature varied between 20.41 and 30.12°C. According to these temperature trends, the best sowing period for the off-dry season is from 5 February to 5 March and the rainy season from 5 July to 10 August.

Effect of factors and their interactions on parameters

The analysis of variance of the observed parameters according to sowing date, sowing method and variety as well as the interactions is shown in Table 3. The analysis showed a highly significant effect of sowing date and variety on height, number of tillers, 50% flowering date and 80% maturity date. The sowing method, with the exception of height, also has a highly significant effect on the observed parameters. Indeed, the different interactions between factors on the parameters have been shown and analysed. It is about: Interaction of date × sowing method × variety (D × MS × V); interaction of date × variety (D × V); interaction of sowing mode × variety (V × MS).

Interaction of date × sowing method × variety (D × MS × V) on the parameters

The analysis of variance revealed a highly significant interaction ($p<0.001$) between the different factors studied (date × sowing method × variety) and a highly significant effect ($p<0.001$) for all parameters studied (height, number of tillers, 50% flowering and 80% maturity).

Height

The analysis of variance showed a very significant interaction between date × sowing method × variety ($p<0.001$). According to the sowing dates, the analysis showed a significant difference. Varieties had average height of 83 cm for sowing between January and June, while for sowing between September and December; varieties had an average height of 59 cm. The highest height (89.35 cm) was obtained at D11 (sowing in august) and the lowest height (53.91 cm) was obtained at D13 (sowing in September) (Figure 2a). A difference in height was observed between rice varieties with ISRIZ 03 having the highest height (78.32 cm) and the control variety NERICA_S_44 having the lowest height (63.33 cm) (Figure 2b). This decrease in the height of the rice varieties would be related to the temperatures of each sowing period. Indeed, the minimum temperatures recorded between January and June increased from 13 to 24°C, while the minimum temperature recorded between September and December decreased from 24 to

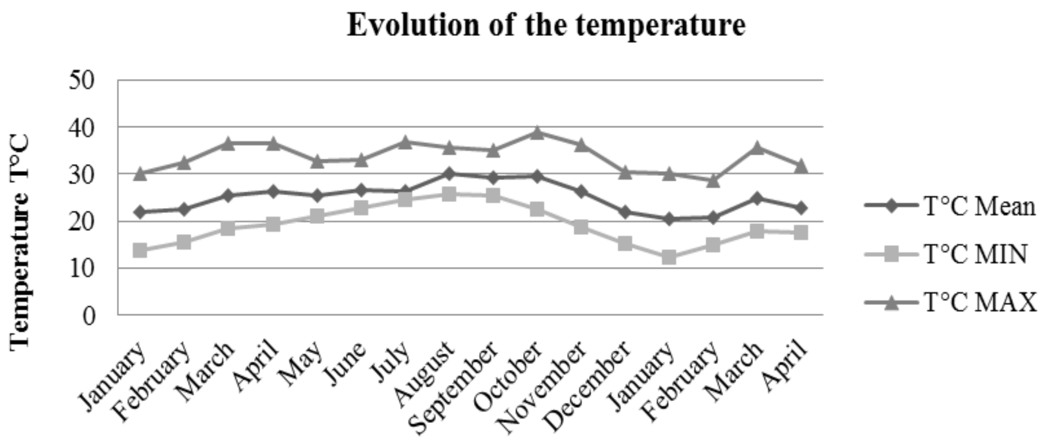

Figure 1. Evolution of the temperature at the test site between January 2017 and April 2018.
Source: Authors

Table 3. Source of variation, degree of freedom and the mean square of the analysis of variance and the interaction between the different factors on the rice paddy parameters studied.

Source of variation	Mean of squares						
	Date (D)	Sowing method (MS)	Varieties (V)	V×D	V×MS	D×MS	V×D×MS
d.f	12	1	11	132	11	12	127
HAUT	2.2e-16***	0.268630	2.2e-16***	2.2e-16***	0.080839	3.584e-12***	0.003856***
TALL	2.2e-16***	2.2e-16***	2.2e-16***	8.805e-14***	1.796e-15***	2.2e-16***	2.2e-16***
50% FLO	2.2e-16***	2.2e-16***	2.2e-16***	2.2e-16***	3.935e-9***	2.2e-16***	2.2e-16***
80%MAT	2.2e-16***	2.2e-16***	2.2e-16***	2.2e-16***	2.076e-9***	2.2e-16***	2.2e-16***

HAUT: Height; TALL: Number of tillers; 50%FLO: days of 50%flowering; 80%MAT: days of 80% maturity.
Source: Authors

12°C. These results are in agreement with Abdul Aziz et al. (2006) and Akram et al. (2007), who showed that rice height was significantly affected by sowing dates. The good behaviour of varieties sown between January and June could be explained by the weak effect of minimum temperature on the mi-flowering phase of the varieties, and corroborates the results of Goita et al. (2017). Sowing between February and March in the hot dry season and sowing between July and August in the rainy season give better heights than late sowing.

This is line with the work of Bashir et al. (2010), Gravois and Helms (1998) and Saikia et al. (1989), who showed that early sowing of rice gives good heights. This decrease in the height of the rice varieties would be related to the temperatures of each sowing period. On the other hand, the analysis of variance showed a non-significant difference in relation to the sowing mode. This means that the broadcasting or transplanting method had no effect on the height of rice regardless of the sowing date (Figure 2c).

Number of tillers

The analysis of variance, showed a highly significant interaction of date × sowing method × variety on number of tillers. Thus the highest number of tillers per meter square was obtained at D2 (sowing on 26 January) and the lowest number of tillers per meter square was obtained at D18 (sowing in December) (Figure 3a). The maximum number of tillers was produced by the control variety Sahel 108 188.70 tillers/m^2 and the minimum was produced by the new variety ISRIZ 03 with 79.60 tillers/m^2 (Figure 3b). As for the sowing method, the number of tillers produced by direct seeding is higher than the number of tillers produced by transplanting (Figure 3c). The difference in the number of tillers according the sowing method is linked to sowing rate.

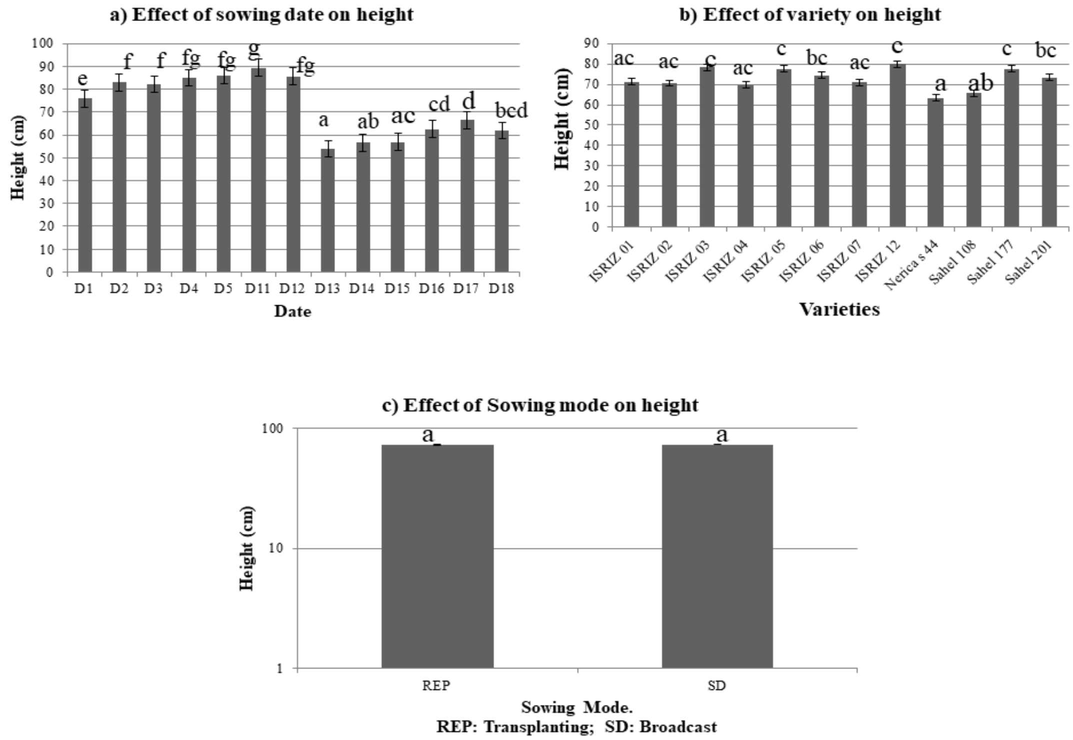

Figure 2. Effect of sowing date; sowing method and variety on height. The bars represent the averages and standard deviations of two repetitions. The different lower case letters indicate statistically significant differences between treatments (P < 0.05; ANOVA, Tukey test).
Source: Authors

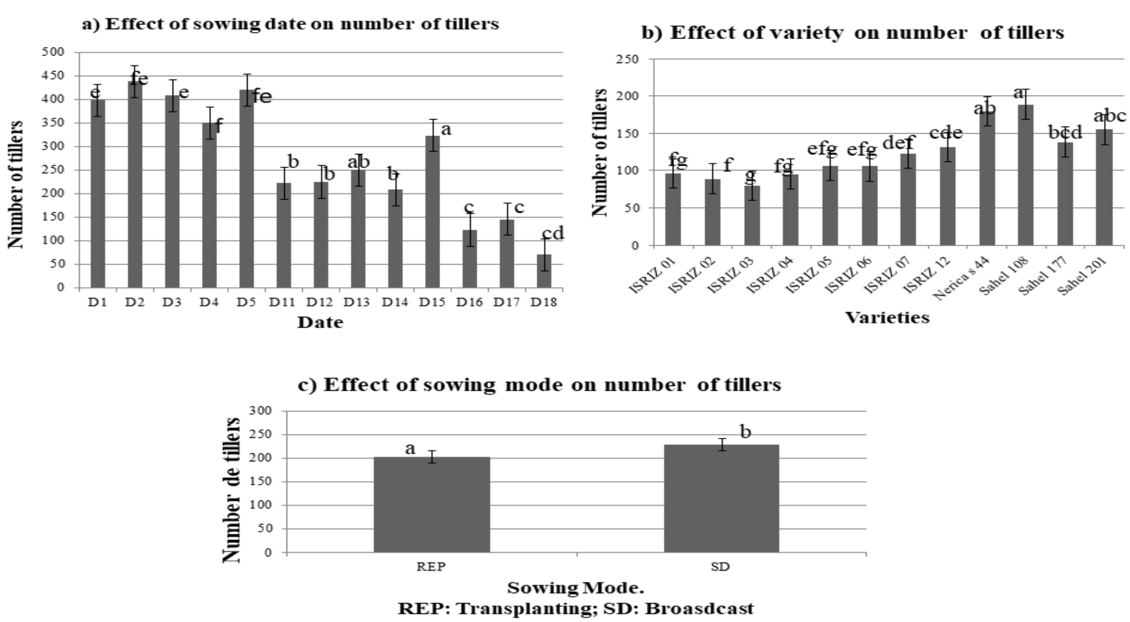

Figure 3. Effect of sowing date; sowing method and variety on number of tillers. The bars represent the averages and standard deviations of two repetitions. The different lower case letters indicate statistically significant differences between treatments (P < 0.05; ANOVA, Tukey test).
Source: Authors

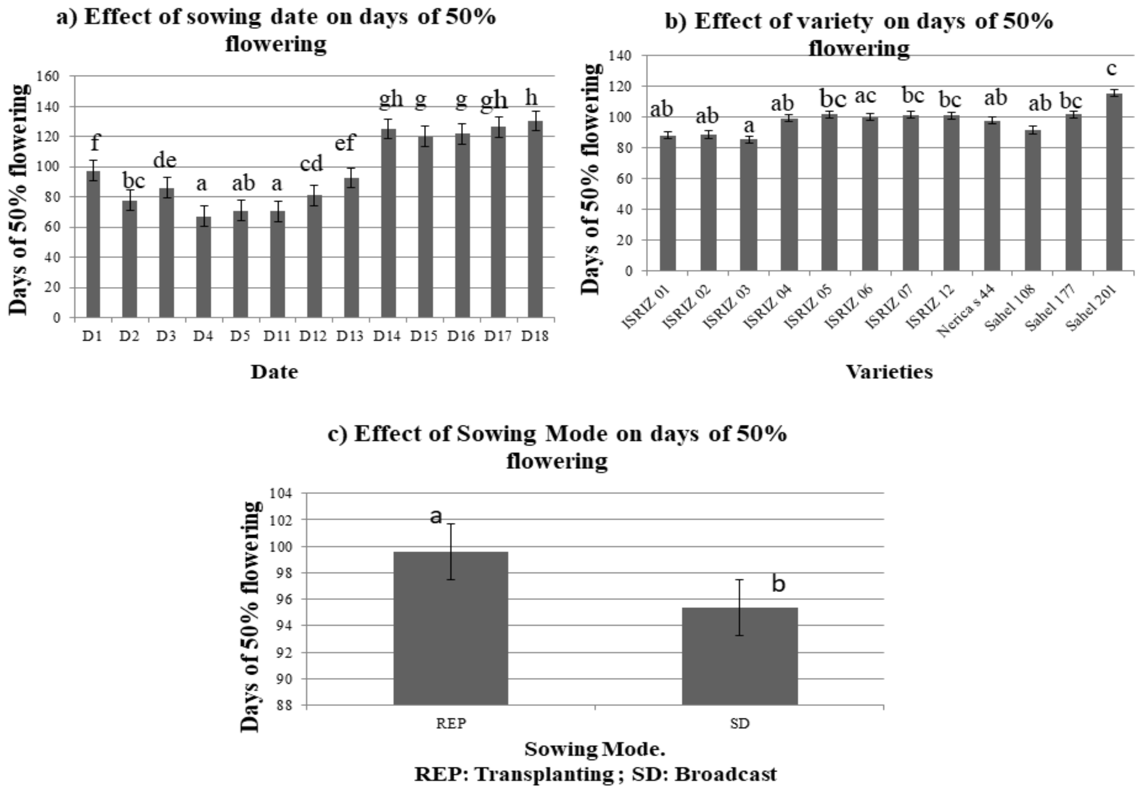

Figure 4. Effect of sowing date; sowing method and variety on days of 50% flowering. The bars represent the averages and standard deviations of two repetitions. The different lower case letters indicate statistically significant differences between treatments (P < 0.05; ANOVA, Tukey test).
Source: Authors

Indeed, the quantity of seed used in direct seeding mode is reducing by half in transplanting mode. This results in a higher density of plants in direct seeding mode. However, the sowing date is the main factor influencing tillering. Sowing between February and June, when the temperature is between 20 and 30°C, favours good tillers development, contrary to sowing between October and January when the temperature drops to 12°C, which limits tillers development; this confirms the work of Bashir et al. (2010), who showed that the temperature impacts tillers development. Indeed, the varieties ISRIZ 01, ISRIZ 02, ISRIZ 03 and ISRIZ 04 produced less than 100 tillers per meter square, that is, 95.9, 88.9, 79.6 and 95.3, respectively, while the varieties NERICA_S_44; Sahel 108 produced more tillers per meter square.

Days of 50% flowering

The analysis of variance of date × sowing method × variety on 50% flowering showed a highly significant interaction (p<0.001) at the 5% threshold. The days of 50% flowering varied from 85.2 to 115.4. According to the sowing date, the maximum day taken to reach 50% flowering was 130.45 observed at date D18 (sown in December) while the minimum day was 67.10, observed ate date D4 (sown in March) (Figure 4a). The control variety Sahel 201 took 115.4 days (highest number of days) to reach this stage, while the new variety ISRIZ 03 took 85.2 days which is the minimum number of days. This difference in days to reach 50% flowering confirms that the varieties tested are different from each other and have different cycles (Figure 4b). For the January sowings (D1), when the temperature is between 15 and 20°C, the varieties reached 50% flowering after more than 90 days (Figure 4b). This trend was more remarkable for the D17 and D18 sowings (sown on December 7 and 28th respectively) where temperature were below 15°C. These low temperatures resulted in 50% lengthening of the varieties. Temperature affects two critical processes in rice production in the sahel: the length of the growth cycle and the sterility of the spikelet, induced by heat or cold stress (Dingkuhn and Miezan, 1995). From date D3 to D12, the days of 50% flowering

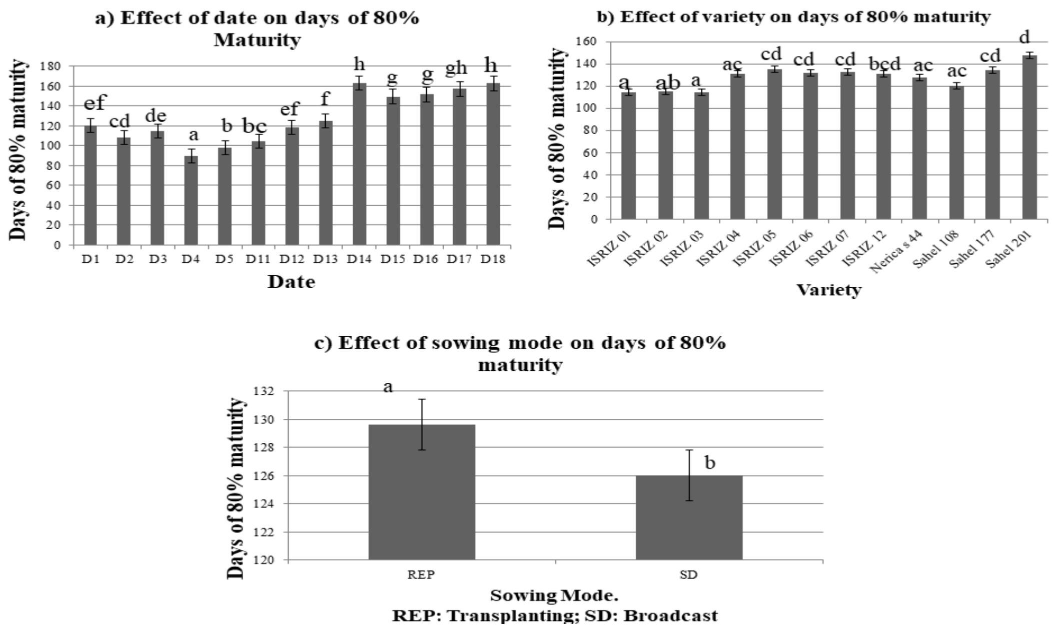

Figure 5. Effect of sowing date; sowing method and variety on days of 80% maturity. The bars represent the averages and standard deviations of two repetitions. The different lower case letters indicate statistically significant differences between treatments ($P < 0.05$; ANOVA, Tukey test).
Source: Authors

of the varieties did not increase compared to the normal length of the growth cycle. Between these sowing dates (March-September), minimum temperatures are between 20 and 26°C and are optimal for good rice development. According to Wopereis et al. (2008), cold temperatures during the vegetative phase slow down the development of rice and thus lengthen the cycle. Low temperature in the vegetative stage can cause slow growth and reduced seedling vigour (Ali et al., 2006), low seedling numbers, reduced tillering (Shimono et al., 2002), and increased plant mortality (Baruah et al., 2009; Farrell et al., 2006; Fujino et al., 2004) increase the growth period (Alvarado and Hernaiz, 2007) and at the reproductive stage, it can cause panicle sterility and a decrease in production and yield (Shimono et al., 2002). Depending on the sowing method, the days of 50% flowering stage was reached more often with broadcast than transplanting (Figure 4c). This difference in days between direct seeding and transplanting is thought to be due to transplanting shock experienced by the transplanted rice paddy seedlings.

Days of 80% maturity

The analysis of variance of date × sowing method × variety on 80% maturity showed a highly significant interaction. The control variety Sahel 201 has the longest cycle (147.4 days) and ISRIZ 03 is the variety with the shortest cycle, while the highest number of days (162.6) was obtained at date D18 (sowing in December) and the shortest (89.5) was obtained at date D4 (sowing in March) (Figure 5a and b). Sabouri et al. (2008) showed the effect of different sowing dates on the maturity of different rice genotypes. In cold regions with short seasons, rice takes a long time to mature or even longer to become sterile. As with the days of 50% flowering, the direct seeded varieties reached 80% maturity earlier than the transplanting would be due to the transplanting shock. Indeed, transplanting implies a change of environment for the young seedlings and they are cut off from their hydro-mineral network. Thus, the young seedlings have to re-establish their root system in their new environment to connect to the hydro-mineral network, while direct seeded rice develops rapidly (Huang et al., 2011; Wu et al., 2019). In addition no till rice also regulates its physiological processes by changing the concentration of endogenous hormones in the plant body during low temperature stress (Wang et al., 2021).

Effect of interaction *date × variety* on parameters and ANOVA probability

Table 3 shows the analysis of date × variety on the parameters studied. Indeed, the analysis showed a highly

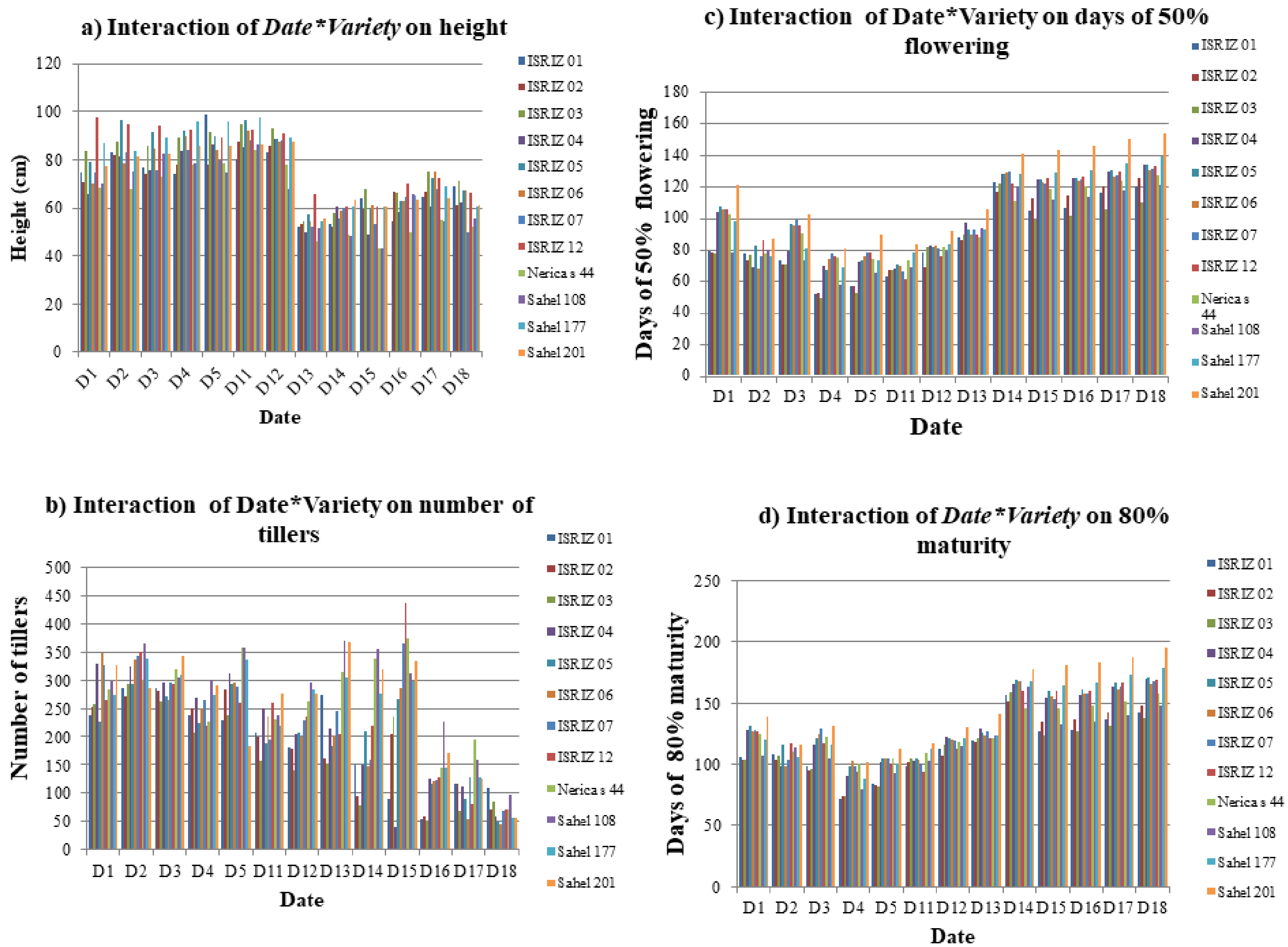

Figure 6. Effect of interaction date x variety on height (a), number of tillers (b); days of 50% flowering (c) and days of 80% maturity (d).
Source: Authors

significant interaction for all parameters (height, number of tillers, days of 50% flowering and days of 80% maturity). The combination of sowing date and variety (Figure 6) had effect on parameters such as height, number of tillers, days of 50% flowering, and days of 80% maturity. Low temperatures and low humidity related to sowing date strongly affect rice growth (Kuwagata et al., 2012). This effect is even more significant for sowing periods when temperatures were below 20°C. Sowing date and variety have a significant impact on height and number of tillers (Praveen et al., 2018). Early sowing allows the plants to benefit from better environmental conditions, especially temperature and solar radiation (Shehzad et al., 2012). Wang et al. (2021) demonstrated the effect of low temperature and variety on rice height.

Effect of *sowing mode* × *variety* on parameters and ANOVA probability

Analysis of the interaction between sowing mode and variety showed that the interaction was highly significant on the number of tillers, the date of 50% and the date of 80% maturity (Table 3). On the other hand, the MS × V combination had no effect on height (p<0.08). Therefore, the sowing method did not influence height regardless of the sowing date. However, with the increase in global temperature and the appearance of periods of extremes, rice in direct sowing often suffers from low temperatures at the sowing stage compared to transplanted rice (Peng et al., 2007; Wang et al., 2021). In contrast, Lawali et al. (2018) demonstrated in their study that early and late

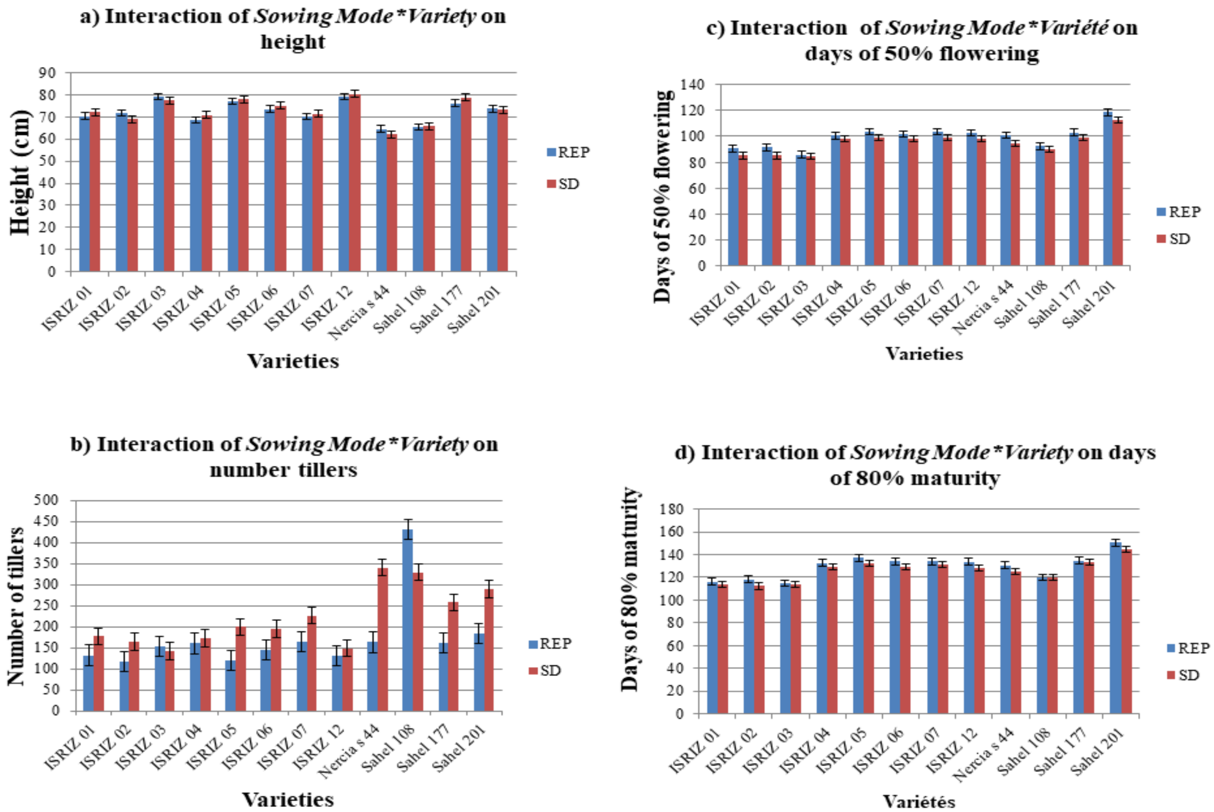

Figure 7. Effect of interaction *Sowing_Mode*×*Variety* on height (a), number of tillers (b), 50% flowering (c) and 80% maturity (d) of rice paddy.
Source: Authors

transplanting of seedlings has an impact on flowering and maturity date in millet. They show in the same study the number of tillers is significant for both early and late transplanting (Lawali et al., 2018). Direct seeding is practiced more than transplanting because of cost reduction and operational simplicity (Wang et al., 2021). Therefore, the sowing method did not influence height regardless of the sowing date (Figure 7)

Principal component analysis (PCA) and hierarchical ascending classification (HAC)

Principal component analysis

The principal component analysis carried out on the variables studied showed the correlations between height (HAUT), number of tillers (TALL), days of 50% flowering and days of 80% maturity. Axes 1 and 2 represent 91.52% of the variable information. Thus, height is negatively correlated with the number of tillers but it is positively correlated with the cycle (days of 50% flowering and days of 80% maturity). These results are in agreement with the results of Do et al. (2020). These authors conducted studies on the agro-morphological characterisation of fonio and demonstrated the negative correlation between height, number of tillers and cycle. The number of tillers is positively correlated with the cycle and there is a strong correlation between the days of 50% flowering and the days of 80% maturity. These results corroborate those of BA (2020), who also showed in his studies that the days of 50% flowering is positively correlated with the days of 80% maturity. The principal component analysis carried out on the variables studied showed the correlations between height (HAUT), number of tillers (TALL), days of 50% flowering and days of 80% maturity (Figure 8)

Hierarchical ascending classification

Figure 9 shows the classification of the varieties according to the parameters studied. Three groups of varieties were determined (Figure 9).

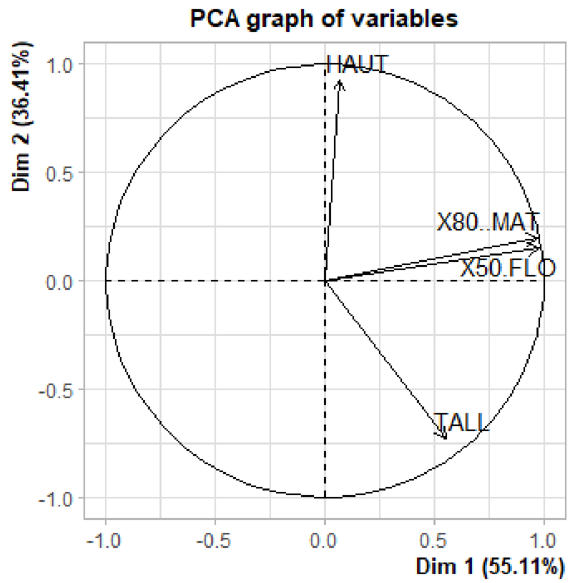

Figure 8. Correlation circle.
Source: Authors

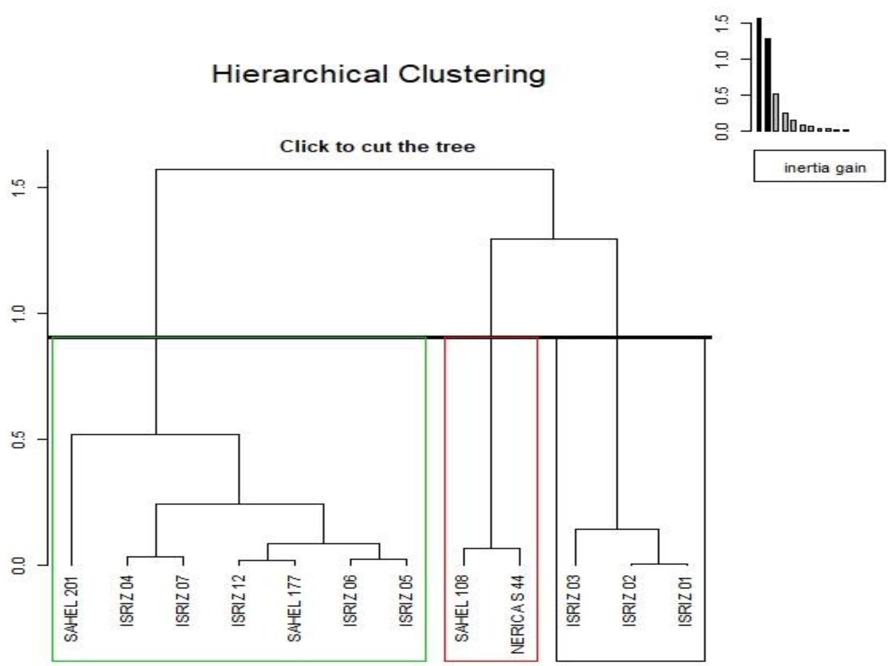

Figure 9. Classification dendrogram.
Source: Authors

Indeed, three groups of varieties can be distinguished according to the production cycle and the production period. Group 1 consists of the short-cycle varieties ISRIZ 01, ISRIZ 02 and ISRIZ 03, which are more tolerant of low temperatures and are suitable for double-cropping rice in the Senegal River Valley (SRV). The second group is made up of SAHEL108 and NERICA-S-44, which are considered to have a short cycle, but are slightly longer than those in the first group, and the third group is made up of varieties with a medium or long cycle. These are ISRIZ 04, ISRIZ 05, ISRIZ 06, ISRIZ 07, ISRIZ 12, SAHEL177 and SAHEL 201. The second group is made up of SAHEL108 and NERICA-S-44, which are considered to have a short cycle, but are slightly longer than those in the first group, and the third group is made up of varieties with a medium or long cycle. These are ISRIZ 04, ISRIZ 05, ISRIZ 06, ISRIZ 07, ISRIZ 12, SAHEL177 and SAHEL 201. These medium and long cycle varieties, if not sown at the right date, can easily suffer the effects of low temperatures. These results are in line with those of Faghani et al. (2011), who showed that timely sowing allows rice plants to better express their potential and to better adapt to extreme temperature conditions (cold and heat). Similarly, Vange and Obi (2006) showed in their study that NERICA varieties sown between June and July in Nigeria favour good adaptation, but studies under our fluctuating climatic conditions show that sowing between July and August favours the adaptation of ISRIZ varieties.

Conclusion

The results of this on-station study highlighted newly released rice varieties that showed good adaptation to the fluctuating climatic conditions in the Senegal River Valley (SRV). Thus, these results validate the hypothesis that the new ISRIZ varieties released by the *Institut Sénégalais de Recherches Agricoles* would adapt better to these climatic fluctuations and would allow for double cropping. However, the climatic conditions, mainly the low temperatures (12-18°C) associated with each sowing date, had a negative effect on the vegetative behaviour of the varieties. Similarly, the choice of sowing method is a very important element to promote good rice productivity. The timely cultivation of rice paddy under the fluctuating climatic conditions in the SRV can be effective for the practice of double cropping, but also improve productivity, so that the choice of a better sowing date and suitable sowing method can allow rice to benefit from the better conditions related to these sowing dates to accommodate the low temperatures. In times of low temperatures, the practice of transplanting promotes a better adaptation of rice paddy. In the future, it would be desirable to carry out a modelling study to predict the behaviour of these varieties over a long period of 10 to 20 years.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors thank the *Centre de Recherches Agricoles* of the Senegalese Institute of Agricultural Research of Saint-Louis through the Agricultural Research support Program of the International Fund for Agricultural Development (IFAD), for financial and technical support. They also thank Professor Anicet Georges Bruno MANGA, who spared no effort in proofreading and editing this manuscript.

REFERENCES

Abdul Aziz K, Zubair M, Mansoor M, Khalid N, Shah IH, Abdul W, Ilyas M, Iqbal A (2006). Agronomic and Morphological Parameters of Rice Crop as Affected by Date of Transplanting. Journal of Agronomy 5(2):248-250. Available at: https://doi.org/10.3923/ja.2006.248.250

Akram HM, Ali A, Nadeem MA, Iqbal MS (2007). Yield and yield components of rice varieties as affected by transplanting dates. Journal of Agricultural Research 45(2):105-111.

Ali MG, Naylor REL, Matthews S (2006). Distinguishing the effects of genotype and seed physiological age on low temperature tolerance of rice (*Oryza Sativa* l.). Experimental Agriculture 42(3):337-349. Available at: https://doi.org/10.1017/S0014479706003619

Alvarado AJR, Hernaiz LS (2007). Antecedentes generales sobre el arroz en Chile. Available at: https://biblioteca.inia.cl/handle/20.500.14001/7145

Ba M (2020). Caractérisation agro-morphologique pour le fort rendement et la tolérance à la salinité de 300 lignées de riz *(Oryza sativa L.)*. Université Gaston Berger.

Baruah AR, Ishigo-Oka N, Adachi M, Oguma Y, Tokizono Y, Onishi K, Sano Y (2009). Cold tolerance at the early growth stage in wild and cultivated rice. Euphytica 165(3):459-470.

Bashir M, Akbar N, Iqbal A, Zaman H (2010). Effect of different sowing dates on yield and yield components of direct seeded coarse rice (Oryza sativa L). Pakistan Journal of Agricultural Sciences 47:361‑365.

Dingkuhn M, Miezan KM (1995). Climatic determinants of irrigated rice performance in the Sahel—II. Validation of photothermal constants and characterization of genotypes. Agricultural Systems 48(4):411-433.

Do AM, N'da HA, Akanvou L, Sokouri DP (2020). Caracterisation agro-morphologique des accessions de fonio (*Digitaria exilis*) collectees au nord de la Cote d'Ivoire. Agronomie Africaine 32(2):169-182.

Faghani R, Mobasser HR, Dehpor AA, Kochaksarai ST (2011). The effect of planting date and seedling age on yield and yield components of rice (Oryza sativa L.) varieties in North of Iran. African Journal of Agricultural Research 6(11):2571-2575.

Fall AA (2007). Le riz, une denrée stratégique à problème, dossier sur la sécurité ou souveraineté alimentaire. Agrovision, bulletin d'informations trimestriel-CMA/AOC, 3.

Farrell TC, Fox KM, Williams R L, Fukai S, Lewin LG, Farrell TC, Fox KM, Williams RL, Fukai S, Lewin LG (2006). Minimising cold damage during reproductive development among temperate rice genotypes. II. Genotypic variation and flowering traits related to cold tolerance screening. Australian Journal of Agricultural Research 57(1):89-100. Available at: https://doi.org/10.1071/AR05186

Faye ON, Fall AA (2018). Introduction de variétés ISRIZ aromatiques et variétés de riz à faible teneur en amylose à la conquête du marché urbain Sénagalais. Série Fiches Techniques 48:3. ISRA-ISSN 0850-9980

Fujino K, Sekiguchi H, Sato T, Kiuchi H, Nonoue Y, Takeuchi Y, Ando T, Lin SY, Yano M (2004). Mapping of quantitative trait loci controlling low-temperature germinability in rice (*Oryza sativa* L.). Theoretical and Applied Genetics 108(5):794-799.

Godwin DC, Meyer WS, Singh U (1994). Simulation of the effect of chilling injury and nitrogen supply on floret fertility and yield in rice. Australian Journal of Experimental Agriculture 34(7):921-926. Available at: https://doi.org/10.1071/ea9940921

Goita O, Traore K, Diwara B, Coulibaly MM, N'diaye MK, Guindo SS, Timbely D, Sako D (2017). Etude de l'effet de la date de semis et de l'age des plantules au repiquage sur le rendement de trois varietes de riz adoptees dans les perimetres irrigues villageois des regions de Tombouctou et de Gao. Agronomie Africaine 29(1):11‑17.

Gravois KA, Helms RS (1998). Seeding date effects on rough rice yield and head rice and selection for stability. Euphytica 102(2):151-161.

Guo Z, Cai L, Liu C, Huang C, Chen Z, Pan G, Guo T (2020). Global analysis of differentially expressed genes between two Japonica rice varieties induced by low temperature during the booting stage by RNA-Seq. Royal Society Open Science 7(6):192243. Available at: https://doi.org/10.1098/rsos.192243

Haefele SM, Wopereis MCS, Schloebohm AM, Wiechmann H (2004). Long-term fertility experiments for irrigated rice in the West African Sahel : Effect on soil characteristics. Field Crops Research 85(1):61-77.

Huang M, Ibrahim Md, Xia B, Zou Y (2011). Significance, progress and prospects for research in simplified cultivation technologies for rice in China. The Journal of Agricultural Science 149(4):487-496. Available at: https://doi.org/10.1017/S0021859610001097

Imin N, Kerim T, Weinman JJ, Rolfe BG (2006). Low Temperature Treatment at the Young Microspore Stage Induces Protein Changes in Rice Anthers. Molecular and Cellular Proteomics 5(2):274-292.

Johnson K, Brown ME (2014). Environmental risk factors and child nutritional status and survival in a context of climate variability and change. Applied Geography 54:209-221. Available at: https://doi.org/10.1016/j.apgeog.2014.08.007

Kuwagata T, Ishikawa-Sakurai J, Hayashi H, Nagasuga K, Fukushi K, Ahamed A, Takasugi K, Katsuhara M, Murai-Hatano M (2012). Influence of Low Air Humidity and Low Root Temperature on Water Uptake, Growth and Aquaporin Expression in Rice Plants. Plant and Cell Physiology 53(8):1418-1431.

Lawali MN, Alhassane A, Traoré B, Sarr B, Seidou O, Balla A (2018). Effets de la transplantation de jeunes plants sur la croissance et le développement du mil au Niger. Cameroon Journal of Biological and Biochemical Sciences 26:6-15.

Mamun EA, Alfred S, Cantrill LC, Overall Rl, Sutton BG (2006). Effects of chilling on male gametophyte development in rice. Cell Biology International 30(7):583-591.

Matlon PJ, Seck A, Consultative Group on International Agricultural Research, Africa Rice Center (2011). Boosting Africa's rice sector: A research for development strategy, 2011-2020. https://ricenewstoday.com/wp-content/uploads/2017/03/Boosting-Africas-Rice-Sector-2011-2020.pdf

Ohno H, Banayo NPMC, Bueno C, Kashiwagi J, Nakashima T, Iwama K, Corales AM, Garcia R, Kato Y (2018). On-farm assessment of a new early-maturing drought-tolerant rice cultivar for dry direct seeding in rainfed lowlands. Field Crops Research 219:222-228.

Peng M, Bi YM, Zhu T, Rothstein SJ (2007). Genome-wide analysis of Arabidopsis responsive transcriptome to nitrogen limitation and its regulation by the ubiquitin ligase gene NLA. Plant Molecular Biology 65(6):775-797. Available at: https://doi.org/10.1007/s11103-007-9241-0

Praveen K, Bm M, Mehera B (2018). Effect of different dates of sowing on growth and yield attributes of different cultivars of wheat (Triticum aestivum L.) under Allahabad condition. Journal of Pharmacognosy and Phytochemistry 7:3443-3446.

Sabouri H, Rabiei B, Fazlalipour M (2008). Use of Selection Indices Based on Multivariate Analysis for Improving Grain Yield in Rice. Rice Science 15(4):303-310. Available at: https://doi.org/10.1016/S1672-6308(09)60008-1

Saikia L, Chandra K, Mahanta T C (1989). Performance of late transplanting rice in Assam. International Rice Research News Letter 14(1):21.

Shehzad M, Ayub M, Ahmad AH, Yaseen M (2012). Influence of priming techniques on emergence and seedling growth of forage sorghum (*Sorghum bicolor* L.). Journal of Animal and Plant Sciences 22:154−158.

Shimono H, Hasegawa T, Iwama K (2002). Response of growth and grain yield in paddy rice to cool water at different growth stages. Field Crops Research 73(2):67-79. Available at: https://doi.org/10.1016/S0378-4290(01)00184-8

Sie M (1997). Analyse des contraintes photothermiques en vue de l'adaptation des variétés de riz irrigué au Sahel. Montpellier. (Doctoral dissertation, Thèse de doctorat. École Nationale Supérieure Agronomique de Montpellier, Montpellier, France).

Tukey JW (1949). Comparing Individual Means in the Analysis of Variance. Biometrics 5(2):99‑114. Available at: https://doi.org/10.2307/3001913

Vange T, Obi I (2006). Effect of planting date on some agronomic traits and grain yield of upland rice varieties at Makurdi, Benue state, Nigeria. Journal of Sustainable Development in Agriculture and Environment 2(1):0794-8867.

Wang W, Chen L, Liu Y, Zeng Y, Wu Z, Tan X, Shi Q, Pan X, Zeng Y (2021). Effects of humidity-cold combined stress at the seedling stage in direct-seeded indica rice. Environmental and Experimental Botany 191:104617. Available at: https://doi.org/10.1016/j.envexpbot.2021.104617

Waongo M, Laux P, Kunstmann H (2015). Adaptation to climate change : The impacts of optimized planting dates on attainable maize yields under rainfed conditions in Burkina Faso. Agricultural and Forest Meteorology 205:23-39. Available at: https://doi.org/10.1016/j.agrformet.2015.02.006

Wopereis M, Defoer T, Idinoba P, Diack S, Dugué M (2008). Manuel technique. Référence 11: Les effets de la température sur le développement du riz.

Wu X, Hao Z, Hao F, Zhang X (2019). Variations of compound precipitation and temperature extremes in China during 1961–2014. Science of the Total Environment 663:731−737. Available at: https://doi.org/10.1016/j.scitotenv.2019.01.366

Xu Q, Yuan X, Wang S, Feng Y, Yu H, Wang Y, Yang Y, Wei X, Li X (2016). The genetic diversity and structure of indica rice in China as detected by single nucleotide polymorphism analysis. BMC Genetics 17(1):53. Available at: https://doi.org/10.1186/s12863-016-0361-x

Yoshida S (1981). Fundamentals of Rice Crop Science. International Rice Research Institute, Los Baños, Laguna, Philippines P 269.