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Combined influence of sowing dates and fertilization on phenology and growth parameters of a late variety of millet (*Pennisetum glaucum* (L.) R. Br.), grown in Korhogo (Côte d'Ivoire)

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Abstract

The rainfall anomalies due to climate change, which result in a greater occurrence of pockets of drought during the cropping cycle coupled with the decline in soil fertility, disrupt cereal production. To cope with this situation, new cultivation practices must be considered. It is in this context that this study was undertaken in Korhogo, in the Center-North of Côte d'Ivoire. Its objective was to determine the effects of sowing date and fertilization on the phenology and growth parameters of a late variety of millet. Thus, two trials were set up according to an experimental set-up in randomized complete blocks with three repetitions, with the main factor being the sowing date and the fertilizers as a secondary factor. The results showed that the vegetative phase received sufficient water unlike the reproductive phase regardless of the sowing date. Phenologically, the combined action of the different sowing dates and fertilization influenced the variety of millet studied. Our results show a shortening of the vegetative phase at the second sowing date due to the known photosensitivity of late millet. With regard to the growth parameters, mineral manure favored better growth and good development of the plants at sowing 2. However, the sowing date 1 was the most suitable for a good evolution of these parameters.

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Introduction

Millet (*Pennisetum glaucum* (L.) R. Br.), is considered, as the most cultivated millet species. Its cultivation covers more than 21 million hectares, globally, where nearly 500 million people depend on it, for their survival (Kadri *et al.*, 2019). It is used, as well, for human and animal food by the quality of its fodder (Bouzou, 2009). Adapted to difficult conditions (poor soils, low rainfall), millet is the most drought-resistant cereal. Hence its importance for local populations, where climatic conditions do not allow sorghum, maize and rice to develop normally (Guengant *et al.*, 2004).

In Côte d'Ivoire, millet is grown throughout the northern region of the country. Most of the cultivated varieties used by farmers are of the traditional type (late millet), and are characterized by a long cycle 120-140 days (Beninga, 2015). In this part of the country, the annual rainfall, varying from 1000 to 1600 mm (Diomandé, 2002), well distributed, can ensure a satisfactory harvest of this cereal (Béninga and Ankanvou, 2005).

With an annual production in 2019 of 65000 tons on an area of 78168 ha (Faostat, 2019), millet ranks third among the cereals produced and consumed in this country, after rice and corn. However, this production does not meet domestic demand, estimated at 120000 tons per year. Yields per hectare are still very low in rural areas (500 kg/ha) (Beninga and Ankanvou, 2005; Beninga, 2007) due to numerous biotic (diseases, weeds, birds) and abiotic constraints (declining soil fertility, poorly productive local equipment) (Kouakou *et al.*, 2013).

To these constraints are added those caused by climate change and its consequences (Boko *et al.*, 2016). Indeed, in cereal production areas such as northern Côte d'Ivoire, sowing dates are regularly shifted due to the delay observed in the start of the rainy season. In addition, the rainfall breaks recorded during the cropping season have various depressive effects on growth, the development and productivity of cereals (Diatta, 2007). Thus, given the importance of millet in the fight against food insecurity, it is necessary to use cultivation practices that raise its level of productivity in high-risk areas.

It is in this context of rainy season disruptions and soil and crop vulnerability (Tabet-Aoul and Bessaoud, 2009 ; Assié *et al.*, 2008), observed in recent years, that this study was conducted in northern Côte d'Ivoire. Its objective is to contribute to the improvement of millet productivity. Specifically, it aims to : (i) to determine the different phenological phases of the millet studied, sown at different dates and subjected to different types of fertilization; (ii) to compare the effect of fertilization and sowing date on the growth parameters of this millet.

Material and methods

Study site

The trial was conducted on the experimental site of the Peleforo GON COULIBALY University located in the Department of Korhogo (9°25' North latitude, 5°38' West longitude and 370 m altitude).

Plant material

The plant material used was a late variety of millet, grown in Côte d'Ivoire. It has a height of 3 to 4 m, a cropping cycle of 120 to 140 days and a yield of 2.5 t/ha in a farming environment. It is photoperiodic of short days and only blooms if the day length is short enough (Beninga, 2015). A well-distributed annual rainfall of 1100 mm to 1300 mm can ensure a satisfactory harvest of this millet variety (Béninga and Ankanvou, 2005 ; Béninga, 2015).

Fertilizer material

Two types of manure were used:

- organic manures : chicken, beef and rabbit droppings. These animals are commonly raised in the commune of Korhogo ; and
- mineral manures: NPKSB (15-15-15 + 6S + 1B) + Urea (46-0-0), in granular form.

Methods

Plots preparation and preliminary operations

Plouwing, followed by levelling and staking, was carried out a few days before the sowing date of each trial. For the preparation of the plots, Pyrical (50 g) was applied to the soil (at a rate of 20 kg/ha). Its use was to control possible insect attacks or other soil microorganisms that could prevent seed germination.

Experimental device, factors and treatments studied

For the implementation of the trials, a Fischer block design, with four levels of fertilization and the control as the main factor, constituted the different treatments. A total of two trials were set up:

- trial 1 (sowing date 1 ; July 09, 2019);
- trial 2 (sowing date 2 ; July 31, 2019).

The treatments studied consisted of :

- control, no fertilizer application or Treatment 1 (T1);
- beef manure or treatment 2 (T2) ;
- rabbit manure or treatment 3 (T3);
- chicken manure or treatment 4 (T4) and
- NPKSB mineral fertilizer (15-15-15 + 6S + 1B) + Urea (46-0-0) or treatment 5 (T5).

The experimental device consisted of a total of 15 elementary plots. The area of an elementary plot was 4.8 m², or 2.4 m x 2 m. Each elementary plot consisted of 4 rows, each with 5 pockets. The seeding geometry adopted was 0.80 m between rows and 0.50 m between pockets in the same row. Alleys of 1 m were left between the elementary plots of the same block and between the blocks.

Conduct of the crop

The sowings were carried out in wet period, by pinching of seeds, in the pockets on partitioned ridges. A total of two trials were set up. The first seeding was conducted on July 09, 2019 and the second on July 31, 2019. Three fertilization operations were performed. The organic manures, were applied at the rate of 10 kg/elementary plot at a rate of 20 t/ha, on the fifteenth (15th) day before sowing. This dose was divided by four taking into account the number of ridges contained in the elementary plots. Thus, the dose of 2.5 kg of organic manure was applied per ridge. For mineral fertilizer, two applications were made. The first application of mineral fertilizer was made, at the time of separation of millet plants from the same pocket, using NPKSB (15-15. 15+6S+1B), at a dose of 4.46 g/pocket, let be a dose of 89.2 g/elementary plot, at a rate of 20 pockets per elementary plot. This dose was applied to the pocket with a capsule at a distance of 5cm from the plant. The second application was made at the beginning of main stem elongation in the form of urea (46-00-00) at a rate of 7.86g/ pocket, let be two capsules per hole at 5cm from the plant. The rate of 157.2g/elementary plot was applied.

For each trial, the separation of millet plants from the same pocket, at 3 plants per pocket, was carried out about 15 days after emergence in order to remove the less vigorous surplus plants. Weeding was carried out as needed in the elementary plots.

Measurements and observations

Phenological observations

Phenological observations were made on the dates of emergence, tillering, elongation of the main stem, earing, flowering and maturity. The sowing-flowering time was determined as follows : date of flowering (DAS) - date of emergence (DAS).

Determination of photosensitivity of the studied millet variety

It is generally accepted in the literature that late millet varieties would be photosensitive to day length (Abdel, 2016). In our experiment, it was determined from the data provided by Anonyme (2019), the day lengths corresponding to the different sowing and flowering dates of the studied millet variety in order to characterize its photosensitivity.

Agro-morphological and rainfall measurements

Agro-morphological measurements were carried out on three pockets taken at random, on the internal lines of each plot. These pockets were chosen to avoid those located on the edges of the elementary plots. Measurements were made at maturity and included plant height (HP), number of tillers per pockets (NT) and number of ears per pockets (NE). At the study site, rainfall measurements were taken using a direct-reading farmer's rain gauge attached to a 2 m high mast after each rainfall.

Data analysis

Data analysis was performed using Excel spreadsheet and XLSTAT statistical software version 2014. The Excel spreadsheet was used to draw graphs and tables. The XLSTAT software was used to evaluate the variance and to study the differences between the means of the different treatments. In case of significant difference, at the 5% threshold, the Newman-Keuls test was used, for the classification of the means into homogeneous groups.

Results

Distribution of rainfall during the cycle of the millet variety studied

The amounts of rainfall, recorded during the stages and phases of development, are presented in table 1. In general, the plants at their different stages of development received more rain in sowing 1 than in sowing 2. Total rainfall amounts of 1035 mm and 837 mm were recorded during the cycle for the first and second sowing dates, respectively. Across both sowing dates, the vegetative phase received significantly more water compared to the reproductive phase. On the first sowing date, 988 mm of rain was recorded during the vegetative phase compared to 47 mm for the reproductive phase. On the other hand, on the second sowing date, 824 mm and 13 mm of rain were recorded for the vegetative and reproductive phases respectively.

Table 1. Rainfall quantities received during the development stages.

Development stages	Rainfall quantities (mm)	
	Sowing 1	Sowing 2
Sowing-Emergence	34	20
Emergence-Tillering	164	311
Tillering-Main Stem Elongation	509	347
Main Stem Elongation-Heading	281	146
Heading-Flowering	33	13
Flowering-Maturity	14	0
Rainfall quantities PV	988	824
Rainfall quantities PR	47	13
Rainfall quantities DC	1035	837

PV : vegetative phase ; PR : reproductive phase ; DC : duration of the cycle

Effects of fertilizers and sowing date on sowing-flowering time

Flowering times as a function of sowing date and fertilizers, are presented in table 2. Statistical analysis showed that there were differences between the means of the treatments, during the two sowing dates ($P<0.001$). The flowering delay at sowing date 1, was shorter in the plants treated with rabbit dung, chicken droppings and NPKSB + Urea mineral fertilizer (98 days). The longest delay (100.33 days) was recorded in the control. At seedling 2, the plants in the rabbit dung and mineral fertilizer (NPKSB + Urea) treatments had the shortest delay (84.33 days), while the untreated plants had the longest delay (88.66 days) on average. Flowering time was influenced by sowing date. It was longer at sowing 1 compared to sowing 2 regardless of treatment.

Table 2. Sowing-flowering times according to seedling date and fertilizers.

Treatments	Sowing-flowering times (j)		
	Sowing 1	Sowing 2	P. value Sowing 1 and Sowing 2/treatment
Control	100.33 a	88.66 a	0.0018
Dg. Beef	98.33 ab	86 ab	0.0050
Dg. Rabbit	98 b	84.33 b	0.0002
Dp.Chicken	98 b	86.33 ab	0.0004
NPKSB+Urea	98 b	84.33 b	0.0002
Average	98.53	85.93	
Probability	P< 0.0001		

Within a column. the means assigned the same letter are not significantly different at the 5% level. Dg : dunging ; Dp : droppings

Effect of sowing date on the duration of the developmental stages of the millet variety studied

The influence of sowing date on the duration of developmental stages in the millet variety studied is presented in fig. 1. The duration of emergence, the tillering and the elongation of the main stem was approximately the same regardless of sowing date. However, the durations of the stages : flag leaf, flowering and maturity were longer in sowing 1 compared to sowing 2 (Fig. 1).

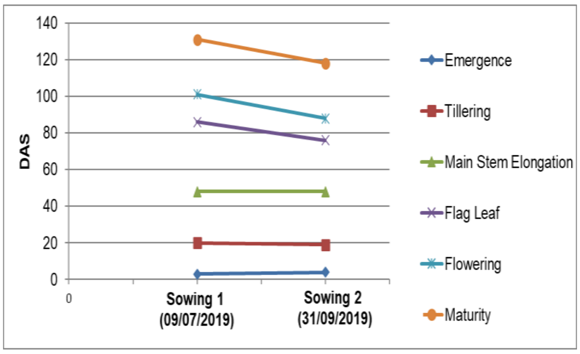

Fig. 1. Effect of sowing date on the average duration of the development stages of the millet variety studied.

Characterization of the photosensitivity of the studied millet variety

Regarding the sensitivity of the studied millet variety to day length. the results showed that the day length was 11 h 53 min and 11 h 49 min respectively for the flowering dates of sowind 1 and sowing 2 (Table 3).

Table 3.I Duration of the day corresponding to the date of flowering.

Observation stages	Dates	Duration of day
Sowing 1	09/07/2019	12 h 39 min
Sowing 2	31/07/2019	12 h 33 min
Flowering sowing 1	18/10/2019	11 h 53 min
Flowering sowing 2	27/10/2019	11 h 49 min

Effect of sowing date and fertilization on growth parameters

The mean values of plant height as a function of sowing date and treatments used are shown in table 4. At the level of plant height, no statistical difference was observed between the means of the treatments during sowing date 1. Plant heights averaged 363.52cm. In contrast at sowing date 2, all treated plants had heights greater than that of untreated plants. It was, on average, 314.47cm compared to 220.4cm for the control plants. Plant height was influenced by sowing date in control plants (Pv = 0.0005), plants fertilized with organic manures {beef dung (Pv = 0 .0035), rabbit dung (Pv = 0.0138) and chicken dropping (Pv = 0.0223)}. At the first sowing date, plants had higher heights (363.52cm) than at the second sowing date (295.66cm).

No significant difference between the means of the treatments at sowing date 1, for the average number of tillers was observed (Table 4). The average number of tillers was 6.82. In contrast at sowing date 2, plants treated with the mineral fertilizer NPKSB + Urea produced more tillers (5.7 tillers) than plants in the other treatments that had similar numbers of tillers. Sowing date only affected the number of tillers of plants fertilized with rabbit dung (Pv = 0.0464) and NPKSB+Urea mineral fertilizer (Pv = 0.0095). The number of tillers produced by the plants in sowing date 1 was higher (6.82 tillers) than those of the plants in sowing date 2 (4.99 tillers).

Table 4. Height, number of tillers and ears according to sowing date and treatments used.

Treatments	Height (cm)			Number of tillers			Number of ears		
	Sowing 1	Sowing 2	P Sowing 1 et 2/traitement	Sowing 1	Sowing 2	P Sowing 1 et 2/traitement	Sowing 1	Sowing 2	P Sowing 1 et 2/traitement
Control	343.1 a	220.4 b	0.0005	5 a	4.4 b	0.4885	5.8 b	4.6 b	0.0456
Dg. Beef	357.7 a	289.4 a	0.0035	6.3 a	5.55 b	0.5062	8.8 ab	6.5 b	0.2796
Dg. Rabbit	376.2 a	321.6 a	0.0138	7 a	4.8 b	0.0464	10.33 a	7.7 b	0.1785
Dp. Chicken	374.6 a	325.7 a	0.0223	6 a	4.5 b	0.1216	10.11 ab	7.4 b	0.1283
NPKSB+Urea	366 a	321.2 a	0.0761	9.8 a	5.7 a	0.0095	9.3 ab	15 a	0.0775
Moyenne	363.52	295.66		6.82	4.99		8.88	8.24	
Probabilité	P< 0.0001						P < 0.0001		

Within a column. the means assigned the same letter are not significantly different at the 5% level. Dg : dunging ; Dp : droppings

The average number of ear by pocket as a function of sowing date and fertilizer treatments is shown in table 4. The results of the statistical test showed a significant difference between the means of the treatments. At the first sowing date, the plants fertilized using rabbit dung generated more ears, with an average of 10.33 ears. The lowest number of ears was produced by the control plants (5.8 ears). At the second sowing date, plants fertilized with mineral fertilizer (NPKSB+Urea) obtained the highest number of ears (15 ears). The lowest number of ears was recorded with the control plants and those fertilized with organic fertilizers with respective averages of 4.6 ; 6.5 ; 7.7 and 7.4 ears. The sowing date only affected the unfertilized plants (Pv = 0.0456). At both sowing dates, the plants had approximately the same number of ears. respectively (8.88 ears) at the first sowing date and (8.24 ears) at the second.

Discussion

In general, the behavior of millet under different types of fertilizers seems to be a function of organic matter inputs and sowing date. The values recorded at the level of phenology during the experimental periods, revealed significant differences.

Plants fertilized with organic or mineral fertilizers were characterized by shorter vegetative phase durations compared to the control. These results could be explained by the availability of mineral elements contained in these fertilizers and their good assimilation by the plant. Indeed, according to Kimuni *et al.* (2014), the effects of mineral fertilizers would be related to the rapid release of fertilizer elements, whereas for chicken manure, the superiority would be related to the combined action of the improvement of soil properties and the rapid mineralization of nutrients.

In our study, the analysis of variance on the influence of sowing dates on the duration of sowing-flowering showed a significant difference between the two dates. This duration was shorter at sowing 2. Moreover, our results showed a reduction in the duration of the developmental stages from the appearance of the flag leaf to maturity at sowing 2 compared to sowing 1.

This shortening observed at the different phenological stages could be explained by the sensitivity of the millet variety studied to day length. Indeed, our results showed that flowering occurred at the same period when day length shortened. This result corroborates those of Abdel (2016) who showed that the growth cycle of late millet varieties changes significantly with sowing date due to their sensitivity to day length. In fact, when sowing takes place during long days, the plant remains in a vegetative state until it reaches an inductive threshold of day length. On the other hand, if the sowing takes place under shorter days, the duration of the vegetative phase becomes very short, but with a minimum value that represents the "intrinsic precocity" of the cultivar. Photoperiodism plays an essential role in the adaptation of millet to conditions of high climatic variability by allowing them to complete their cycle at the end of the rainy season, regardless of the sowing date (Diop, 2005; Abdel. 2016). It is therefore a phenomenon that allows the synchronization of flowering with the end of the rainy season (Vaksmann *et al.*, 1996).

The analysis of the results of the effect of fertilizers on the evolution of the growth parameters showed that at the first sowing date, fertilizers had no significant effect on the height of the plant and the number of tillers, but, they influenced the number of ears. Concerning the second sowing date, the differences were observed in these mentioned parameters. This difference could be explained by the fact that at sowing 2, the control plants did not benefit from the nitrogen flash at the beginning of the season (Clerget, 2004). Thus, the application of fertilizer at this date, particularly mineral fertilizer, had a remarkable effect on these growth parameters for the fertilized plants compared to the control plants. The effect of this fertilizer on the growth parameters could be attributed to the fact that this fertilizer has mineral elements that can be directly assimilated by the plants, which would have favored their rapid growth. As indicated by Ilunga *et al.* (2018), the richness of this mineral fertilizer (NPK) in nutrients, especially, nitrogen which is an essential element for growth, certainly contributes to good plant growth. For Kouassi *et al.* (2019), mineral fertilizer promotes tillering and reduces the senescence of green leaves during the reproductive phase. According to this same author, nitrogen would be a stimulant of vegetative growth. Also Siéné *et al.* (2019), showed that mineral fertilizer increases the number of leaves and ears in millet. The delay in the effect of organic amendment compared to mineral fertilizer would be related to the mineralization rate of organic manures, because. its constituents are not directly available, they must first be mineralized (N'diaye *et al.*, 2019). According to the same author, the application of organic fertilizers to soils increases the availability of growth elements to plants, for their growth and development (Pare, 2014).

Plant height growth, number of tillers, number of ears produced were better at the first sowing date than at the second date. For Baboy *et al.* (2015), late sowing results in slower growth. Also, the difference in height could correspond to a rapid adaptation of plants to drought (Kouressy *et al.*, 2008). It is to be related to the distribution of the amount of rain and the length of the day, during the vegetative phase (sowing - earing). According to Naoura *et al.* (2014), the small size of the plants at sowing 2 is one of the direct consequences of the reduced cycle. Which, according to Traoré *et al.* (2000), is a characteristic specific to photoperiodic plants. With regard to the number of tillers, our results are in agreement with that of Chantereau (2013) who indicated that in photoperiodic varieties, tillering decreases the more the sowing occurs in short days. The work of Siéné *et al.* (2010) showed that the reduction in the number of tillers is related to the duration of the vegetative phase. The difference observed in the number of ears produced according to the sowing dates could be due to the low rate of tillers recorded at sowing 2. According to Chaibou (2013), tillering lasts about 20 days and tillers produced late after this time do not emit ears or even all the tillers emitted do not all arrive at heading (Chantereau. 2013).

Conclusion and perspectives

This study has allowed us to highlight the effect of sowing date and fertilization on the phenology and growth parameters of a late millet variety. It results from this study that, the quantities of water recorded at the first sowing date (sowing 1) were higher than those of the second sowing date (sowing 2). The vegetative phase received sufficient water in contrast to the reproductive phase regardless of the sowing date. The phenology was influenced by the different sowing dates combined with the use of fertilizers (organic and mineral). The results for growth parameters showed that mineral fertilizer had the best effects on all these parameters at sowing 2. Also, the precocious sowing (sowing 1) favored a better growth of the plants contrary to the late sowing (sowing 2).

In view of these results, it would be necessary to consider replicating the trial in other millet-producing agro-climatic area, and to test new sowing dates combined with fertilization in order to evaluate their effects on the agro-morphological parameters and grain yield of millet. The results of these studies would provide indications on the best time to grow millet in the north of Côte d'Ivoire in order to obtain a good yield.

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