



**Original Paper**

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## Evaluation of the hydrogel effect on the growth and yield of okra (*Abelmoschus esculentus*) in an anthropized environment soil in Korhogo the northern part of Côte d'Ivoire

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Received: 06-06-2023

Accepted: 15-08-2023

Published: 31-08-2023

### ABSTRACT

Rational use of fertilizers and irrigation water are concerns to modern agronomy considering an efficient and promising perspective to obtain better yields. This study aimed to evaluate the effects of potassium-based hydrogel on the growth and yield of okra on anthropized soils of Korhogo in Northern Côte d'Ivoire. The experimental design used consisted of three repetitions with the 8-modality hydrogel as the first factor (0 g, 0.1 g, 0.3 g, 0.5 g, 1 g, 2 g, 3 g and 4 g). The second factor was the type of application with 2 modalities: (0 cm and in depth of 6 cm). Control seedlings were established in soils without hydrogel. The results showed that the germination rate, growth and fruit yield of okra were significantly different for the different amounts of hydrogels used. The best results were obtained on plots that received 0.3 g of hydrogel applied at a depth of 6 cm. It was concluded that the rational use of 0.3 g hydrogels not only contributes to germination but also stimulates growth and improves the yield of okra grown on anthropized soils in the town of Korhogo. This quantity of hydrogel is therefore recommended for agricultural use to deal with the constraints linked to water scarcity and soil depletion. © 2023 International Formulae Group. All rights reserved.

**Keywords:** Hydrogel, okra, growth, yield, Korhogo.

### INTRODUCTION

*Abelmoschus esculentus* is a plant cultivated in tropical and subtropical regions of the world (Siddartha et al., 2017). All parts (roots, stem, leaves, fruits and seeds) are valued for food, medicine, crafts and industry (Luo et al., 2018). This species is among the vegetables products with appreciable

nutritional value (Kouassi et al., 2013). Fresh fruits are rich in vitamin C and calcium while dried fruits are rather rich in protein (Céline et al., 2021). Global okra production is estimated at around 8.7 billion tonnes; India being the main okra producing country in the world followed by Nigeria, Pakistan, the United States and Egypt (Kolte and Shivankar, 2023).

In Côte d'Ivoire, people cultivate and consume okra. It is grown throughout the Ivorian territory and the annual production is about 100,000 tons (Kouakou et al., 2020). However, its cultivation is neglected and mostly left to the task of women who generally do not have large cultivable areas. Furthermore, okra production techniques have evolved very little (Fondio et al., 2003) and is not done intensively. It is generally produced during the main rainy season on plots of land, close to large areas of cereal crops (rice, maize) and yams, or dispersed in these fields (Fondio et al., 2001).

In the savanna zone of Côte d'Ivoire, the stakes of okra production are poorly perceived because of its marginalization in relation to cereal and cotton crops. In this region, apart from the low State incentives like all the Ivorian regions, the cultivation of okra is confronted with the lack of adequate inputs and skilled labor, poor cultivation practices, the decline in soil fertility (Yao et al., 2012) and the deficiency of rainfall which result in water constraints (Aziafekey et al., 2013) which can be severe and erratic (Nana et al., 2009).

The assurance of food security can only be effective if innovative prospects are opened up to increase production despite the shortage of rainfall. The rational use of fertilizers and irrigation water are concerns of modern agronomy considered in an efficient and promising perspective to obtain better yields. In such a context, many works relating to the use of hydrogel in agriculture have been carried out (Ekebafé et al., 2013; Amina et al., 2014; Defaa et al., 2015; Atllah and Miloud 2019; Palanivelu et al., 2022). However, the ability to retain and return water to the plant constitutes a real mechanism of the performance of hydrogel use in agriculture to resolve water constraints (Wei and Durian, 2014). Hence, the present study aimed to evaluate the effect of hydrogel on the growth and yield of okra.

## MATERIALS AND METHODS

### Presentation of the study area

The study took place in the Poro Region, located in the North of Côte d'Ivoire, between 5°16 and 16°16 west longitudes and

8°32 and 10°20 north latitude. It occupies an area of 12,500 km<sup>2</sup> and has 4 towns which are as follows: Dikodougou, Korhogo, M'Bengué and Sinematiali. This locality is bounded to the north by the Republic of Mali, to the west by the regions of Bagoué and Béré and to the east by the regions of Tchologo and Hambol. Its climate belongs to the dry tropical climatic regime, of the Sudano-Sahelian type, the rhythm of the seasons of which is regulated by the displacement of the intertropical front (Jourda et al., 2006). It records 800 mm to 1,200 mm of annual rainfall. The average humidity is 65–70% (Kouassi et al., 2018). The average annual duration of sunshine is 2,500 hours, the monthly average being about 250 hours in the dry season compared to nearly 140 hours during the months of July and August (Kouassi et al., 2018). Temperatures vary between 26°C and 37°C (Dramane, 2016). This region is mainly characterized by a combination of more or less desaturated ferrallitic soils and ferruginous soils (Roose, 1979).

## Material

### Fertilizing material

The fertilizer used is the hydrogel commonly known as “solid rain” because it generally comes in granulated form and is packaged in 1 kg and 25 kg boxes. The type of hydrogel used in this study is a technological innovation by Sergio Rico, distributed in Côte d'Ivoire by the commercial structure for agricultural supervision, fruit and vegetable production, promotion and popularization of new irrigation technology and drainage (Terre Chaude). It is a water retainer, copolymer of acrylate and cross-linked potassium acrylamide in the form of bio-fractionable granules, non-toxic and capable of absorbing up to 200 times its weight in water. Its characteristics are recorded in Table 1 and its mode of operation is simplified in Figure 1.

### Plant material

The plant material used in this study is the Kirikou F1 okra variety (Figure 2). The seeds used are those distributed by the TECHNISEM seed structure. These are hybrid

seeds, resistant to diseases with a good yield, a purity of 99% minimum and a Germination rate of 88% minimum.

## Methods

### *Experimental setup*

The study was carried out in Korhogo more precisely in the lowland of Kassirimé. The choice of this site is explained by the density of land used by women for market gardening and its proximity to the city center. This geographical location of the study site made it possible to conduct the experiment meticulously. The experimental design was a Fisher block, with 16 treatments and 03 repetitions, i.e. a total of 48 elementary plots of 5 m x 1 m (5 m<sup>2</sup>) each. Each elementary plot include two border lines and 1 observation line. The spacing between the elementary plots was 1 m and the spacing between the blocks is 2 m.

The experiment consisted in studying the responses of *Abelmoschus esculentus* under the effect of the hydrogel. The hydrogel factor had 8 modalities (Table 2). To do this, for each block, on eight ridges, the 0-60 cm horizon was taken with an auger in order to make pockets. The earth cored from the pockets was mixed with the required quantity of hydrogel then dropped in the holes before sowing. On eight other ridges, the previously measured quantity of hydrogel was spread without mixing, then closed with a thin layer of cored soil before sowing. On the control ridge, sowing was carried out without adding hydrogel.

### *Sowing on the plots*

Thirty minutes after the preparation of the experimental setup, sowing was carried out at a depth of 7.5 cm, respecting the distance of 60 cm between two neighboring pockets, at the rate of 3 seeds per pocket. This operation was carried out on February 2, 2022. Watering was done after sowing since it was not raining during the experimental period. Thinning was carried out 7 days after sowing in order to bring the pockets back to a plant.

### *Nurturing the experimental plant*

Since the study was conducted during the dry season, irrigation was one of the main nurturing operations that were carried out. There was shortage of rainfall, the water regime was a limiting factor for market gardening during the experimental period. Watering was done with backwater water, using a 15 litre watering can. Each watering session lasted an average of 20 minutes. Plants were subjected to five watering regimes for comparison: daily watering, once every 2 days watering, once every 2 days watering, once every 4 days watering, and once every 6 days watering.

### *Data collection*

In the context of this study, two categories of parameters were measured on the plants tested: three growth parameters and one yield parameter. Data collection was done following the principles of experimentation described by Dagnelie (2003). Data on growth parameters were collected on a sample of 153 okra plants.

### *Measuring growth parameters*

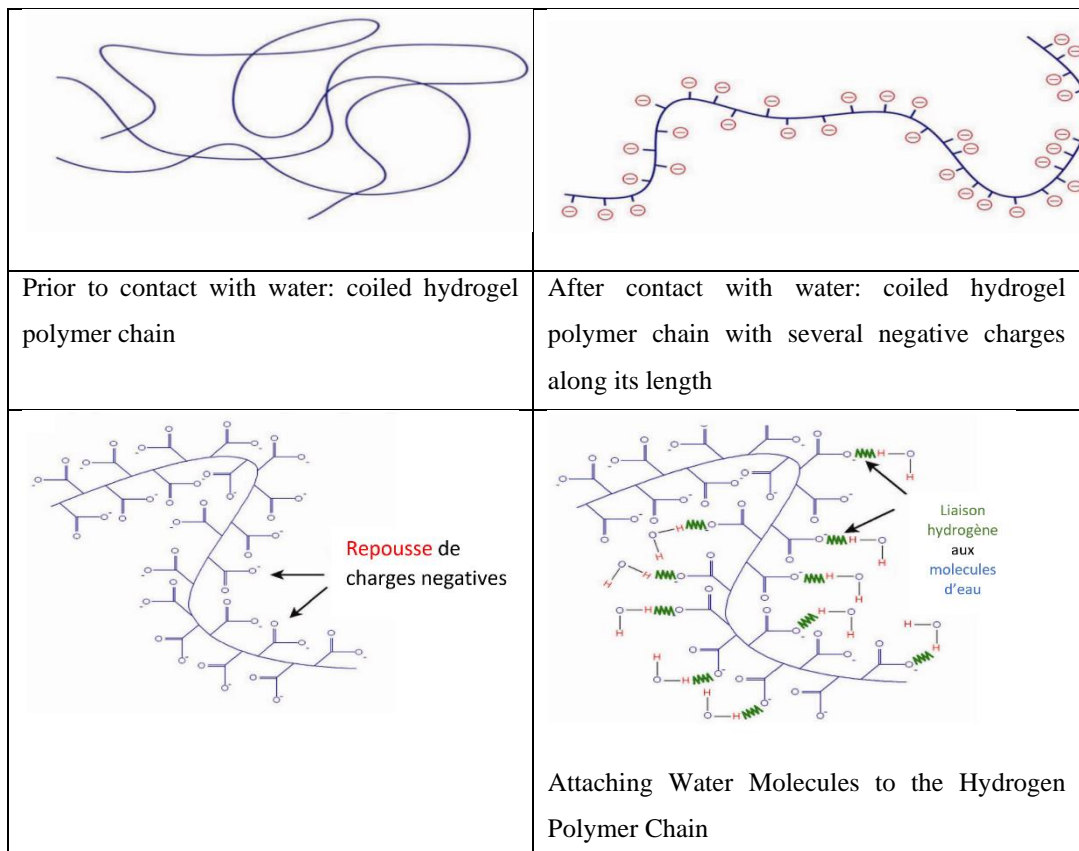
In order to estimate the germination rate, we counted the seeds that had germinated. Nine (9) randomly selected competitive plants in each elementary plot were tagged to record various observations on growth, yield. Plant growth parameters namely: plant height, plant collar diameter, number of leaves per plant, longest leaf length and longest leaf width were recorded 30 days after planting.

### *Data processing and analysis*

The data collected was processed using two software. The 2013 version of the Excel spreadsheet was used to enter the data and draw up the tables and graphs. The XLSTAT 2014 software made it possible to perform analyzes of variance (ANOVA) at the 5% probability threshold. Tukey's test was used to compare each pair of means.

**Table 1:** Features of the hydrogel used in the study.

Parameters	Unit	Features
The appearance		brown pellets
Particle size	Mm	1-5 (or personalized)
Absorption Deionized water	MI/g	> =400
Water retention capacity	MI/l	980
Apparent density	G/cm <sup>3</sup>	0, 56
Water content	%	< 6
PH value	-	7
N: P: K		3.5: 2.3: 27
Product stability with the ground	Year	> =10
Storage time(sec)	Year	> =10
Storage temperature	°C	0 - 35



**Figure 1:** Hydrogel Polymer Water Absorption Mechanism.

Source: Kalhapure et al., 2016.



**Figure 2:** Kirikou F1 okra variety.

**Table 2:** Treatments used in experimentation.

<b>Treatements</b>	<b>Characteristics</b>
T0:	Control without hydrogel
T1:	mixture of 0,1g of hydrogel with soil
T2:	mixture of 0,3g of hydrogel with soil
T3:	mixture of 0,5g of hydrogel with soil
T4:	mixture of 1g of hydrogel with soil
T5:	mixture of 2g of hydrogel with soil
T6:	mixture of 3g of hydrogel with soil
T7 :	mixture of 4g of hydrogel with soil
T8:	mixture of 5g of hydrogel with soil
T9:	5g of hydrogel spread on the ridge (deposit)
T10:	4g of hydrogel spread on the ridge (deposit)
T11:	3g of hydrogel spread on the ridge (deposit)
T12:	2g of hydrogel spread on the ridge (deposit)
T13:	1g of hydrogel spread on the ridge (deposit)
T14:	0.5g of hydrogel spread on the ridge (deposit)
T15:	0,3g of hydrogel spread on the ridge (deposit)
T16:	0,1g of hydrogel spread on the ridge (deposit)

## RESULTS

### Influence of hydrogel on okra germination

Figure 3, illustrating the variations in germination rates according to the different pre-treatments of the substrate and different quantities of hydrogel, shows that the sowing carried out on cored soil mixed with the hydrogel made it possible to have higher germination rates ( $66.7\% \pm 9.6\%$ ), compared to the hydrogel spread without prior mixing with soil ( $22.2\% \pm 10.3\%$ ) (Figure 3). These results are confirmed by the analysis of variance which revealed a very highly significant pretreatment effect on germination rates ( $p < 0.008$ ). The best germination rates was noted for seedlings made on substrates mixed with 0.1 g, 0.3 g and 0.5 g of hydrogel. All the seeds sown on these substrates germinated (Figure 3). It is necessary to observe that on these soils, germination was early because it occurred from the 6th day after sowing. Concerning the plots having received 1 g and 2 g of hydrogel, germination took place on the 7th day after sowing. Germination on soils mixed with 3 g of hydrogel was late since germination took place on the 8th day after sowing. With this last treatment, all the plants from this last category of plot died a few days after having grown. In addition, it should be noted that there was no germination on the plots having received 4 g and 5 g of hydrogel.

### Influence of the hydrogel on the height of Okra during the first month

The highest average plant height ( $7.97 \pm 0.27$  cm) was obtained for the substrates mixed with 0.3 g of hydrogel and the lowest ( $2.90.00 \pm 0.34$  cm) on the hydrogel spread without any prior mixing with the substrate. No significant difference was observed between the plots that received the mixture of 0.3 g of hydrogel with soil and those mixed with 1 g of hydrogel associated with soil (Table 3). The control plots obtained mean stem heights ( $4.00 \pm 0.29$ ) significantly lower than the plots with 0.3 g of hydrogel mixed with the substrate. However, no significant variation was found between plots and other forms of amendment.

### Influence of the hydrogel on the collar diameter

Measurements made on the mean collar diameter for the organic amendments showed a variation from  $13.45 \pm 3.40$  mm (for soils mixed with hydrogel) to  $14.10 \pm 1.50$  mm (for the hydrogel spread without any prior mixing with the substrate). Although the average values recorded on the plots having received the hydrogel spread without any prior mixing have a higher trend, the largest average diameters were obtained with the soil mixtures, at 0.3 and 0.5 g of hydrogel. The collar diameters obtained with these treatments reached  $17.56 \pm 0.92$  mm. The average diameter ( $12.63 \pm 0.98$  mm) of the stems recorded on the control plants were significantly lower than the values obtained with the amendments of 0.3 and 0.5 g of hydrogel mentioned above (Figure 4).

### Influence of the hydrogel on the number of leaves

The results obtained for the average number of leaves per plant one month after sowing varied from  $4.33 \pm 0.43$  (for soils with 3 g of hydrogel spread without prior mixing) to  $7.67 \pm 0.353$  (for 0.1 g of hydrogel mixed with soil). The average number of leaves ( $5.75 \pm 0.37$ ) obtained per plant on the control soils was significantly lower than that recorded on the soils mixed with 0.1 g of hydrogel ( $p < 0.0001$ ). However, no significant difference was noted between the values obtained by the control plants and the other forms of amendment carried out, the p-value being between 0.38 and 0.79. Nevertheless, the values obtained with mixing 0.3 g of hydrogel with the soils were slightly higher than those obtained with control plots (Figure 5).

### Influence of hydrogel on leaf length and width

One month after sowing, the average leaf length per plant varied from  $2.45 \pm 0.40$  cm for plants grown on soils having received 3 g of hydrogel spread without prior mixing to  $7.43 \pm 0.33$  cm for cultivated plants on soil mixed with 0.3 g or 0.5 g of hydrogel. The controls obtained average leaf lengths estimated at 3.75

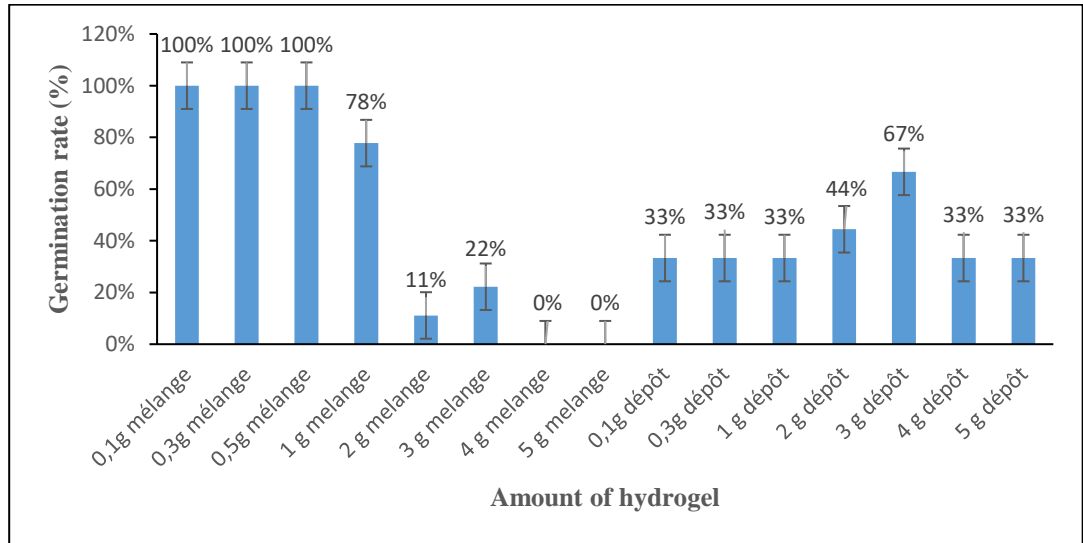
± 0.35 cm. The analysis of variances shows that this value is significantly lower than those of plants grown on soils mixed with 0.3 g or 0.5 g of hydrogel (Figure 6). Contrary, the value of the control is significantly different ( $p < 0.0001$ ) from the length obtained on the plants of the soils mixed with 2 g or 3 g of hydrogel.

The highest average leaf width are plants grown on soils that received 0.5 g or 0.3 g of hydrogel applied without prior mixing. The average width of leaves from these plants was estimated at  $9.30 \pm 0.80$  cm. Lower values are estimated at  $4.87 \pm 0.57$  cm. They were recorded on soils having received 3 g of hydrogel spread without prior mixing. The control plots obtained average leaf widths

evaluated at  $7.14 \pm 0.49$  cm. No significant difference was observed between the control plots and the plots having received one of the types of amendments, with the exception of the plots having received 3 g of hydrogel spread without prior mixing (Figure 7).

**Influence of hydrogel on the number of fruits per plant**

One month later, the total number of fruits per plant varied from  $1.42 \pm 0.22$  for the T11 treatment, to  $2.57 \pm 0.82$  for the T9 amendment. The control plots obtained  $1.47 \pm 0.16$  fruits per plant. However, the amendments obtained no significant variation between them and either with the controls.

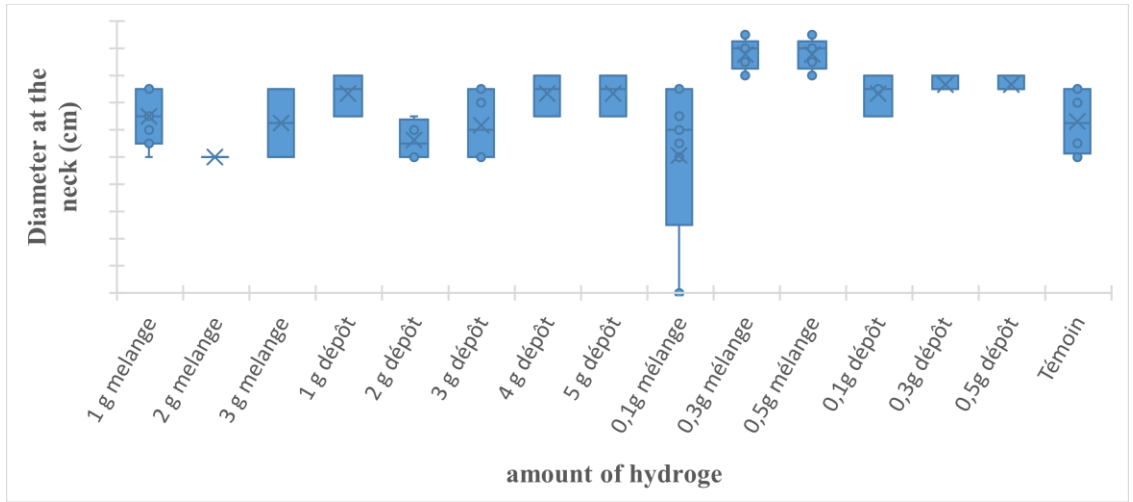


**Figure 3:** Germination rate of okra under the effect of hydrogel.

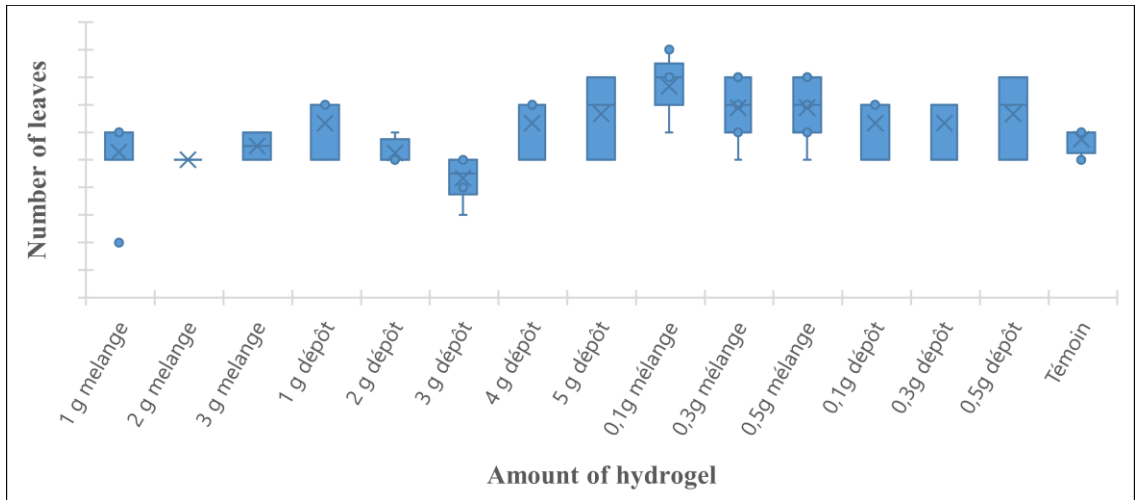
**Table 3:** Combined effect of hydrogel amount and substrate type on okra height 1 month after sowing.

Treatment	Average size (cm)
3 g deposit	$2.90 \pm 0.34$ a
2 g mix	$3.00 \pm 0.83$ a
3 g mix	$3.00 \pm 0.59$ a
2 g deposit	$3.73 \pm 0.42$ ab
Control	$4.10 \pm 0.29$ ab
1 g mix	$4.16 \pm 0.31$ ab
0,1g deposit	$4.33 \pm 0.48$ ab

1 g deposit	4.33 ± 0.48 ab
4 g deposit	4.33 ± 0.48 ab
5 g deposit	4.33 ± 0.48 ab
0,3g deposit	4.67 ± 0.48 ab
0,5g deposit	5.00 ± 0.48 ab
0,1g mix	5.70 ± 0.28 b
0,5g mix	5.70 ± 0.28 b
0,3g mix	7.97 ± 0.28 c

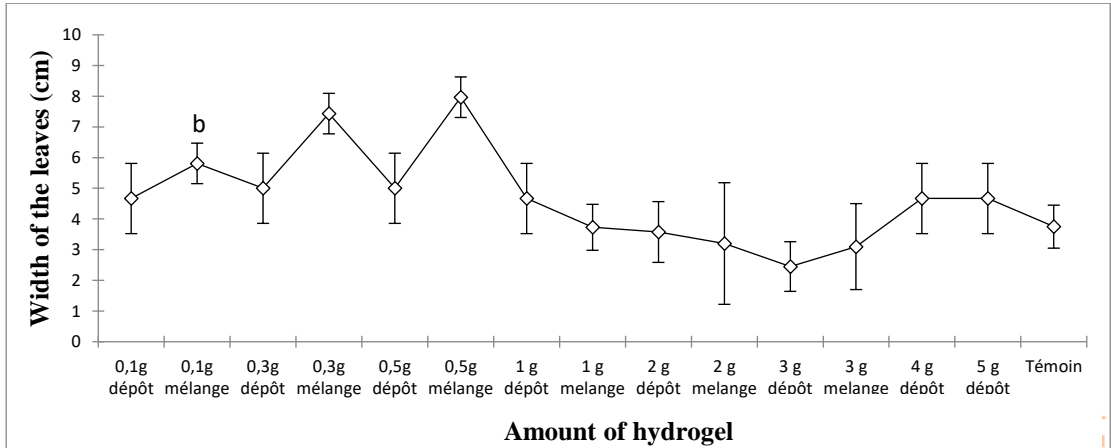


**Figure 4:** Variation in collar diameter of okra 1 month after sowing based on hydrogel quantity and the type of substrate treatment.

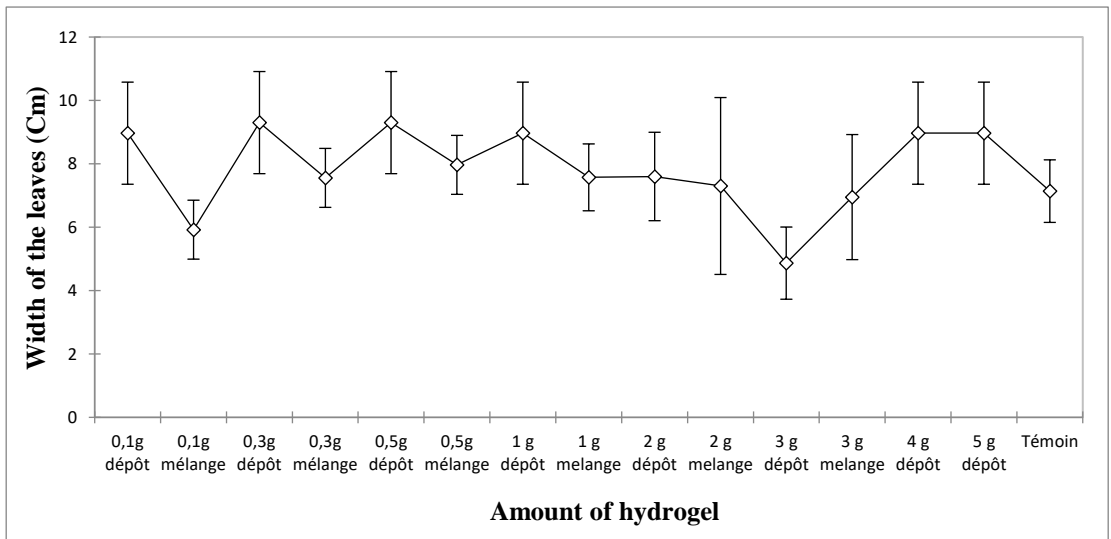


**Figure 5:** Variation in the number of okra leaves 1 month after sowing based on hydrogel quantity and the type of substrate treatment.





**Figure 6:** Variation in the length of okra leaves 1 month after sowing based on the type of hydrogel quantity and the type of substrate treatment.



**Figure 7:** Variation in the width of okra leaves 1 month after sowing depending on the type of hydrogel quantity and the type of substrate treatment.

## DISCUSSION

### Effect of hydrogel on okra germination

The experiment made shows that the hydrogel can play a role in the germination of okra. It was necessary, first, to address the quantities of hydrogel used to verify that a positive influence is indeed exerted on the germination of okra. This process proved to be appropriate because it made it possible to highlight the appropriate fractions: the best results obtained being the sowing carried out

on the substrates mixed with 0.1 g, 0.3 g and 0.5 g of hydrogel. Experiments conducted on okra by Nayan et al. (2018) gave similar results. These authors showed that the germination rate is higher when the hydrogel is incorporated into the soil compared to a soil that does not contain it. The germination rates obtained were around  $17 \pm 0.2$  for soils amended with hydrogel against  $13 \pm 0.3$  for soils without hydrogel (Nayan et al., 2018). The present study has the double merit of not

only defining the optimal quantities favorable to the improvement of germination without adding another material, but also of obtaining higher germination rates.

### **Effect of hydrogel on okra growth and yield**

The good growth of okra plants and high production observed in fertilized soils compared to the control reflect the need to fertilize a deficient soil whose nutrient content would not be sufficient to ensure good plant development (Ognalaga et al., 2016 ; Diallo et al., 2022). The best yield of okra was remarkable with 0.3g of hydrogel brought to the soil. The favorable response of okra in the presence of hydrogel can be explained by an improvement in pH and physical characteristics of the soil. This is because the hydrogel has a pH between 6.0 and 8.0. According to Pernes-Debuyser and Tessier (2002), in soils of temperate regions the cation exchange cation (CEC) can double in a very restricted range of pH (6.0 to 7.5), strongly orienting the physical properties of soils. Therefore, due to this characteristic, hydrogel does not affect the availability of nutrients, the chemical composition of the soil and the action of other agrochemicals such as fertilizers, herbicides, fungicides and insecticides (Narjary et al., 2013). Here, adding the hydrogel to acidic soils raised its organic matter content and therefore the pH of the soil. This rise in pH caused the increase in the canonical exchange capacity. It should be noted that hydrogels improve the physical properties of soils including porosity, bulk density, water holding capacity, soil permeability and infiltration rate (Narjary et al., 2013). According to Thombare et al. (2018), increased porosity results in improved seed germination and seedling emergence rate, root growth and density, and reduced soil erosion, due to reduced soil compaction (Thombare et al., 2018). It also increases biological/microbial activities in the soil, which increases the availability of oxygen/air in the root zone of the plant (El-Rehim et al., 2004). Hydrogels help plants withstand prolonged water stress by delaying the onset of permanent wilting point and reducing crop irrigation requirements due to reduced water

loss through evaporation. The water retained in the root zone of the crop and the leaching of nutrients into the soil are also reduced (Thombare et al., 2018).

### **Conclusion**

Hydrogel soil amendment impacted germination, growth and yield of okra plants. Significantly positive effects on all studied parameters were obtained with 0.3 g and 0.5 g of hydrogel mixed with the substrate at 6 cm depth. In a context characterized by soil degradation and scarcity of water resources induced by climate change, the results of this study showed that the use of hydrogel has improved germination, promoted plants growth and increase the fruit yield per plant. The hydrogel could be considered a good tool for adapting to climate change for an agriculture facing the challenges of managing soil and water resources becoming more and more rare. The rational amendment of the soil in hydrogel therefore seems to be a promising technique for improving the success of operations aimed at restoring ecosystems in an anthropized environment such as that of the city of Korhogo.

### **COMPETING INTERESTS**

The authors declare that they have no competing interests.

### **AUTHORS' CONTRIBUTIONS**

DM, KS, AKA, KA and KBK contributed to the data collection, analysis and processing. data processing. Supervision of this work was by SD and FL. All these authors contributed to the writing of this manuscript.

### **ACKNOWLEDGEMENTS**

The authors would like to thank the management of the TECHNISEM seed company, the UPGC and the village women for their support in carrying out this study.

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