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Full Length Research Paper

Agro-physiological response of millet (*Pennisetum glaucum* (l.) r. br.) to water deficit when augmented with organic fertilization

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The aim of the present study was to assess the impact of water deficit on millet growth and yield parameters under fertilization conditions using laying hen droppings. To achieve this, a split-plot experiment with three replications was carried out, studying two main factors: Water regime (H0: normal watering, H1: 10-day suspension of watering at the vegetative stage, H2: 10-day suspension of watering at 50% flowering stage) and fertilization (D0: 0 g, D1: 240 g/pot). The results showed an increase in height, the number of tillers produced, flower count, ear and grain weight (GW), total dry biomass, and drought resistance index in fertilized plants subjected to water deficit at both the vegetative and 50% flowering stages. However, in unfertilized plants, water deficit applied at the vegetative stage reduced plant height, total dry biomass, and the drought resistance index. Water deficit applied at the 50% flowering stage resulted in a reduction in the number of flowering tillers, ear, and GW of unfertilized plants. Water deficit applied at the 50% flowering stage was significantly more damaging to plants. The results suggest that fertilization with laying hen droppings appears to be beneficial in crop environments subject to pockets of drought, especially at the vegetative stage.

Key words: *Pennisetum glaucum,* laying hen droppings*,* water regime, drought resistance index.

INTRODUCTION

In Burkina Faso, millet ranks third in cereal production, behind maize and sorghum, with a production of 718,000 tonnes in 2021 (FAOSTAT, 2022). This cereal is grown primarily for its grains for human consumption and is one of the staple foods in arid and semi-arid regions of Africa and Asia (Shelke and Chavan, 2010; Dreyer, 2018). Millet fodder is also used to feed livestock (Dakheel et al., 2009; Newman et al., 2010; Hamadou et al., 2017). From a nutritional perspective, millet grains have high nutritional value (Maiti and Rodríguez, 2010), being rich in protein (11.8 g/100 g), fat (6.4 g/100g), dietary fiber (7.8 g/100 g), carbohydrates (72.2 g/100 g), minerals (1.8g/100 g), calcium (221.9 mg/100 g), phosphorus (272 mg/100 g), iron (9.98 mg/100 g), zinc (2.4 mg/100 g), sodium (26.12 mg/100 g), magnesium (158 mg/100 g), thiamine (0.38 mg/100 g), and vitamin A (Wahid and Abdellah, 2020). Millet also has therapeutic effects (Hanane, 2013). Its consumption is recommended for children, convalescents,

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the elderly and pregnant women due to the grain's high calorie content (Bekoye, 2011). Additionally, it is recommended for people with anemia because of its high iron content (Amadou et al., 2013).

However, in terms of millet production, the national yield is less than 1 t/ha (FAOSTAT, 2020). This low yield is partly explained by recurrent climatic changes, sometimes marked by pockets of drought. These pockets of drought create a lack of water for plants, resulting in reduced photosynthesis (Pinheiro and Chaves, 2011), reduced respiration and ion uptake, disrupted metabolism and growth; and in extreme cases, lead to plant death (Ghannoum, 2009; Hayano-Kanashiro et al., 2009; Drugmand, 2020). Faced with the problems caused by pockets of drought, it would be imperative to find effective methods for mitigating the impact of pockets of drought on plants. Previous work on the effect of fertilizers on plant tolerance to water shortage has shown that the use of manure can improve the resistance of rice (Diallo et al., 2010) and okra (Konaté et al., 2016) to water stress. In addition, manure from oxen, rabbits and hens would also improve the resistance of maize to water stress (Siéné et al., 2020). Studies carried out by Sory et al., 2022 on the effect of laying hen droppings on millet production showed that these droppings significantly improved millet yield. However, there is little information on the impact of these droppings on resistance to water stress in millet. The aim of the present study is to assess the impact of water deficit on growth and yield parameters of millet under droppings-based fertilization conditions.

MATERIALS AND METHOD

Study site

The study was carried out in the garden of the ˋUnité de Formation et de Recherche en Science de la Vie et de la Terre˝(UFR/SVT) of Joseph Ki-Zerbo University, located in the center of Ouagadougou, the capital of Burkina Faso. Geographically, the site is located at latitude 12° 22' 46" North and longitude 1° 30' 3" West. Ouagadougou's climate is Sudano-Sahelian, with average annual rainfall ranging from 600 to 900 mm.

Plant material

The study focused on a hybrid millet variety named "Nafagnon" supplied by the Institut Nationale de l'Environnement et de Recherche Agricole (INERA) based in Kamboinsé. This variety was chosen for its high yield (4 t/ha), resistance to mildew (incidence < 10%), tolerance to ergot and smut, and early cycle.

Physic-chemical characteristics of soil and laying hen droppings

Four samples were taken from the study soil to make up the composite sample. This sample was submitted to the Bureau National des Sols (BUNASOLS) for granulometric and physic-chemical analysis. The results showed that the weakly acidic soil (pH = 5.39) has a sandy-loam texture (80.39% sand, 9.81% silt and 9.8% clay) with relatively low organic matter (5.63%) and C (3.26%) contents (Table 1). It contains 0.29% total N, 4.89 ppm assimilable P, 0.64% assimilable K, 1.86 g/kg total Mn and 4.67 g/kg total Ca, reflecting its low mineral content. Laying hen droppings used as fertilizer are slightly basic (pH = 7.19) with a high OM (83.74%), C (48.57%) and dry matter (96.28%) content (Table 2). It is also rich in total N (6.75%), assimilable Pp (2.29%) and assimilable K (2.82%) (Table 2).

Experimental setup

The experimental setup was a randomized split-plot with 3 replications, with the following factors studied: water regime at 3 levels (H0: no suspension of watering, H1: suspension of watering for 10 days at vegetative stage, H2: suspension of watering for 10 days at 50% flowering stage) and fertilization at 2 levels (D0: 0 g/pot; D1 (240 g/pot). In all, the plants were subjected to 6 treatments: H0D0 (plants not subjected to watering suspension and not fertilized), H0D1 (plants not subjected to watering suspension and fertilized with 240 g/pot of droppings), H1D0 (plants subjected to a 10 days watering suspension at vegetative stage and not fertilized), H1D1 (plants subjected to a 10 days watering suspension at vegetative stage and fertilized with 240 g/pot of droppings), H2D0 (plants subjected to a 10 days watering suspension at 50% flowering stage and not fertilized), H2D1 (plants subjected to a 10 days watering suspension at 50% flowering stage and fertilized with 240 g/pot of droppings). In the setup, treatments represent sub-blocks, blocks represent replicates and 6 pots per treatment represent the experimental unit.

Conducting the test

The experiment was conducted in 20-liter pots, each containing 20 kg of soil. Laying hen droppings were added at a dose of 240 g in 20 kg of soil in each pot, and mixed before sowing. After watering the contents of each pot to field capacity, seedlings were sown at 04 grains per pot. At the 14th day after sowing (DAS), the number of plants was reduced to one per pot, followed by a suspension of watering for 10 days corresponding to the water deficit at the vegetative stage (H1). On the 54th DAS, corresponding to the 50% flowering date, the H2 water deficit was applied by suspending watering for 10 days. At the end of each water deficit, watering was resumed on the 24th DAS (H1) and 64th DAS (H2) every other day until maturity.

Collecting data

Data were collected on the last days of water stress, i.e. 24th DAS for water deficit at vegetative stage and 64th DAS for water deficit at 50% flowering stage. Plant height was measured on 64th DAS using a decameter. On 24th DAS, the number of tillers produced per plant was counted for all water regimes. At harvest, ear weight per plant, GW per plant and total dry biomass were determined by weighing with a 0.01 g precision electronic balance. The drought resistance index was determined as the ratio of the dry biomass of unfertilized, non-water-deficient plants to the dry biomass of water-deficient, fertilized and unfertilized plants.

Data analysis

Excel 2013 was used to produce the graphs. Xlstat version 2016 was used to check data distribution using the Shapiro-Wilk test.

Table 1. Soil physic-chemical properties.

Variable	Features	Quantities
Texture	Clay (%)	9.8
	Silt (%)	9.81
	Sand (%)	80.39
OM and C	Total organic matter (%)	5.63
	Total C (%)	3.26
N	Total N (%)	0.29
	C/N	11
P	Assimilable P (ppm)	4.89
K	Assimilable K (ppm)	32.96
Mn	Total Mn (g/kg)	2.74
Ca	Total Ca (g/kg)	4.67
Na	Total Na (mg/kg)	948.66
Chemical factors of soil fertility per 100 g	Ca^{2+} (meq)	2.5
	Mg^{2+} (meq)	1.86
	K^+ (meq)	0.64
	Na^+ (meq)	0.28
	Sum of exchangeable bases (meq)	5.28
	Cation exchange capacity (meq)	8.25
	Saturation rate (%)	64
Ground reaction	pH (H_2O)	5.39

Analysis of variance (ANOVA) was also used to study variability between treatments. Means were compared using the Newman-Keuls test at the 5% threshold.

RESULTS

Plant height

As shown in Figure 1, under water-deficit conditions, fertilized plants (H1D1, H2D1) recorded an increase in plant height compared with plants without water deficit and not fertilized (H0D0). In addition, fertilized plants that suffered a water deficit at the vegetative stage (H1D1) or at the 50% flowering stage (H2D1) have a taller height than plants that suffered the water deficit at both stages without fertilization (H1D0, H2D0) (Figure 1). Compared with the height of plants without water deficit and without fertilization (H0D0), water deficit applied at the vegetative stage to plants not fertilized (H1D0), reduced plant height, while at the 50% flowering stage water deficit applied to plants not fertilized (H2D0) did not affect plant height (Figure 1). Water deficit applied at the vegetative stage had a negative impact on plant height compared with that applied at the 50% flowering stage. Analysis of variance showed that plant height was significantly affected by fertilization (*P* = 0.000), water regime (*P* = 0.001) and the interaction of water regime and fertilization (*P* = 0.046).

Number of tillers produced and flowered per plant

Analysis of variance showed a significant effect of fertilization ($P < 0.0001$) and water regime (*P* = 0.01) on the number of tillers per plant, while the interaction of water regime and fertilization had no significant effect on the number of tillers per plant (*P* = 0.59). In fact, the number of tillers of plants subjected to water deficit and fertilization (H1D1, H2D1) was higher than that of plants with no water deficit and no fertilization (H0D0). Under the same water conditions, the number of tillers of plants subjected to water deficits and fertilization (H1D1, H2D1) is higher than that of unfertilized plants subjected to water deficits (H1D0, H2D0). The number of tillers of fertilized plants subjected to water deficit at 50% flowering is higher than that of fertilized plants subjected to water deficit at the vegetative stage (Figure 2A).

As shown in Figure 2B, the number of flowering tillers on plants that have undergone watering suspension and

Table 2. Chemical properties of laying hen droppings.

Variable	Features	Quantities
Organic matter and carbon	Total OM (%)	83.74
	Dry matter (%)	96.28
	Total C (%)	48.57
Nitrogen	Total N (%)	6.75
	C/N	7
Phosphorus	Assimilable P (%)	2.29
K	Assimilable K (%)	2.82
Magnesium	Total Mn (g/kg)	1.13
Calcium	Total Ca (g/kg)	5.97
Sodium	Total Na (mg/kg)	834.02
Ground reaction	pH (H_2O)	7.19

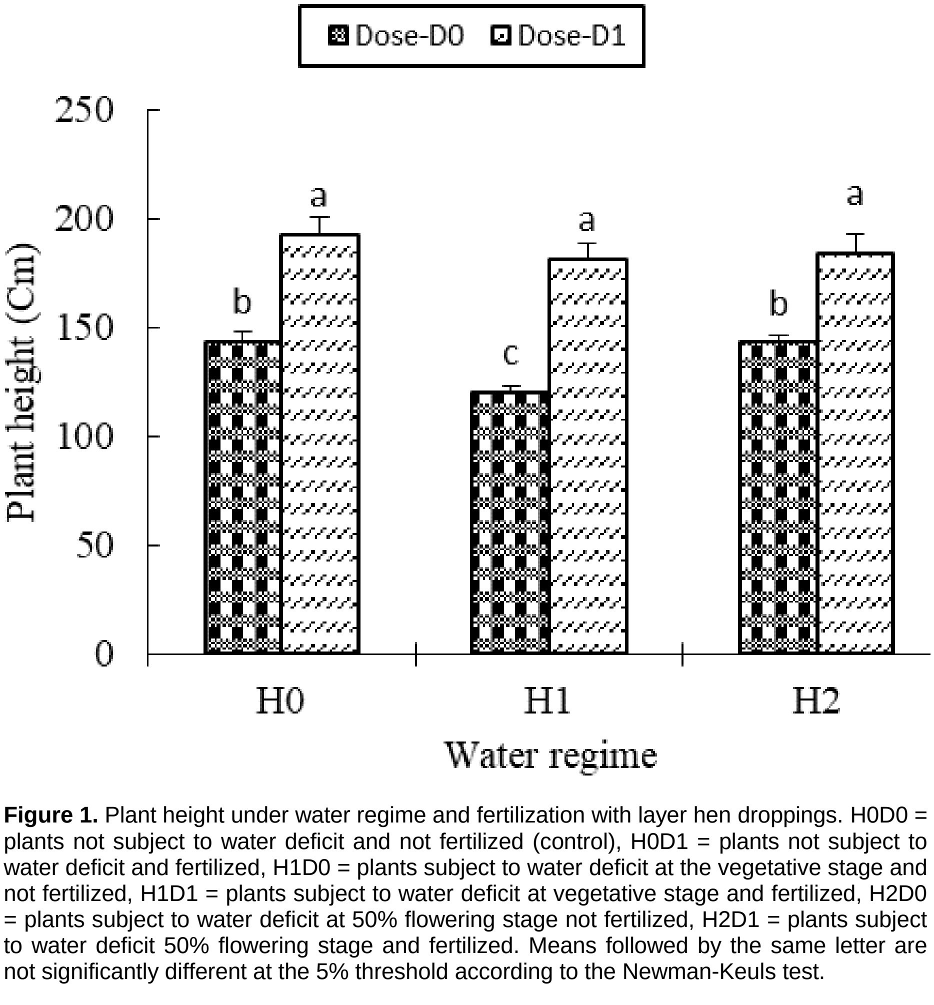

Figure 1. Plant height under water regime and fertilization with layer hen droppings. H0D0 = plants not subject to water deficit and not fertilized (control), H0D1 = plants not subject to water deficit and fertilized, H1D0 = plants subject to water deficit at the vegetative stage and not fertilized, H1D1 = plants subject to water deficit at vegetative stage and fertilized, H2D0 = plants subject to water deficit at 50% flowering stage not fertilized, H2D1 = plants subject to water deficit 50% flowering stage and fertilized. Means followed by the same letter are not significantly different at the 5% threshold according to the Newman-Keuls test.

fertilization (H1D1, H2D1) is higher than on unfertilized plants that have not undergone water deficit (H0D0). However, the number of flowering tillers of unfertilized plants subjected to water deficit at the 50% flowering

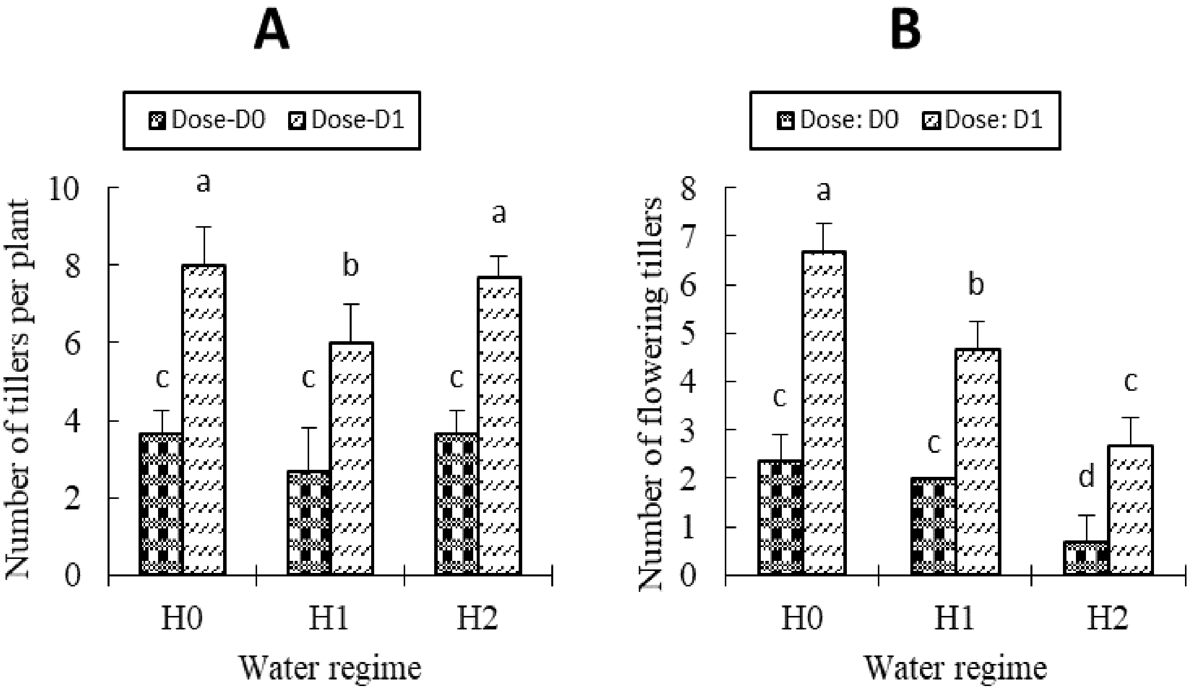

Figure 2. Number of tillers produced (A) and flowering (B) of plants grown under water regime and fertilized with laying hen droppings.

stage (H2D0) is lower than that of unfertilized plants not subjected to water deficit (H0D0). Under water deficit conditions at the vegetative and 50% flowering stages, the number of flowering tillers of fertilized plants (H1D1, H2D1) is much higher than on non-fertilized plants (H1D0, H2D0). In addition, there was a reduction in the number of flowering tillers on plants subjected to water deficit at the 50% flowering stage, compared with plants subjected to water deficit at the vegetative stage (Figure 2B). The results of the analysis of variances showed significant effects of water regime ($P < 0.0001$), fertilization ($P < 0.0001$) and the interaction of water regime and fertilization ($P = 0.007$) on the number of flowering tillers.

Ear weight and GW per plant

As shown in Figure 3A, the ear weight of fertilized plants subjected to water deficit at the vegetative (H1D1) and 50% flowering (H2D1) stages is higher than that of unfertilized plants watered daily (H0D0). On the other hand, the weight per plant of unfertilized plants subjected to water deficit at 50% flowering (H2D0) was lower than that of unfertilized plants watered daily (H0D0). The ear weight of fertilized plants subjected to water deficit at vegetative (H1D1) and 50% flowering (H2D1) stages was higher than that of unfertilized plants subjected to water deficit at both stages (H1D0, H2D0). Of the 2 water deficits, which applied at the 50% flowering stage induced a reduction in ear weight compared with that applied at the vegetative stage (Figure 3A). Statistical results showed significant effects of fertilization ($P < 0.0001$) and water regime ($P < 0.0001$) on ear weight, but the interaction ($P = 0.37$) did not significantly impact ear weight.

As shown in Figure 3B, the GW of plants subjected to water deficit at the vegetative stage and fertilized (H1D1) is higher than that of plants not fertilized and not subjected to water deficit (H0D0). However, the GW of plants subjected to water deficit at the 50% flowering stage and fertilized (H2D1) or not fertilized (H2D0) is lower than that of plants not fertilized and not subjected to water deficit (H0D0). Under water deficit conditions at the vegetative stage, the GW of fertilized plants (H1D1) is much higher than that of unfertilized plants (H1D0). The water deficit at the 50% flowering stage was detrimental to the plants, with a sharp reduction in GW compared with the water deficit applied at the vegetative stage (Figure 3B). The results of statistical analysis revealed significant effects of water regime ($P < 0.0001$), fertilization ($P < 0.0001$) and the interaction of water regime and fertilization ($P = 0.02$) on GW.

Total dry biomass per plant and drought resistance index

As shown in Figure 4A, the total dry biomass of plants subjected to water deficit at vegetative and flowering

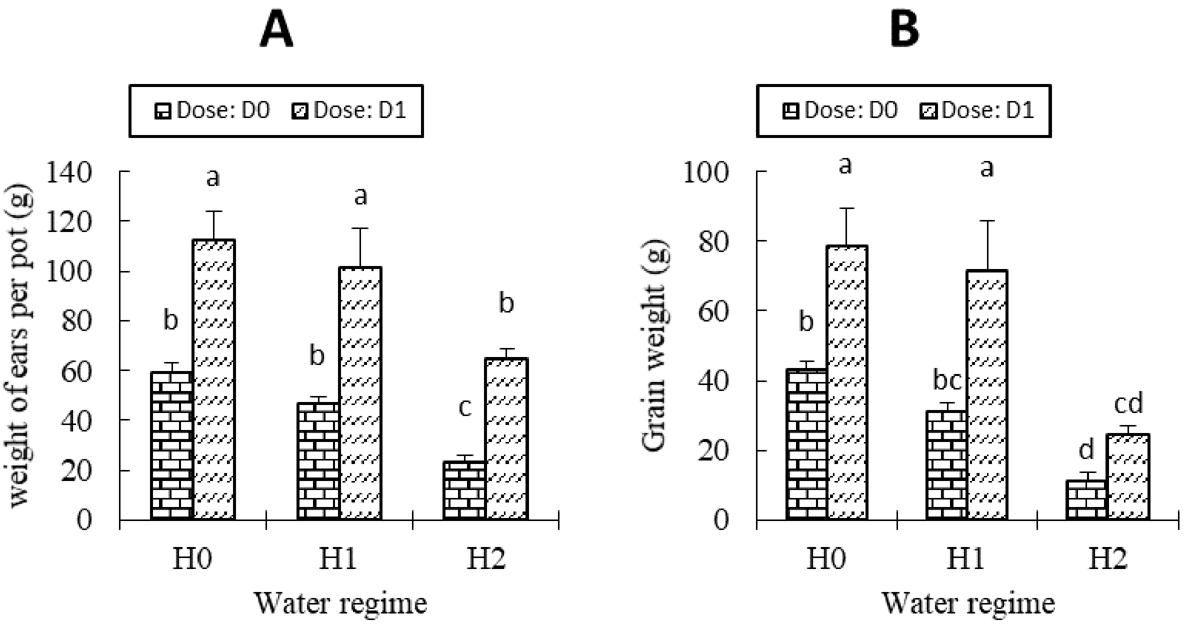

Figure 3. Ear weight (A) and GW (B) of plants grown under water regime and fertilized with layer hen droppings.

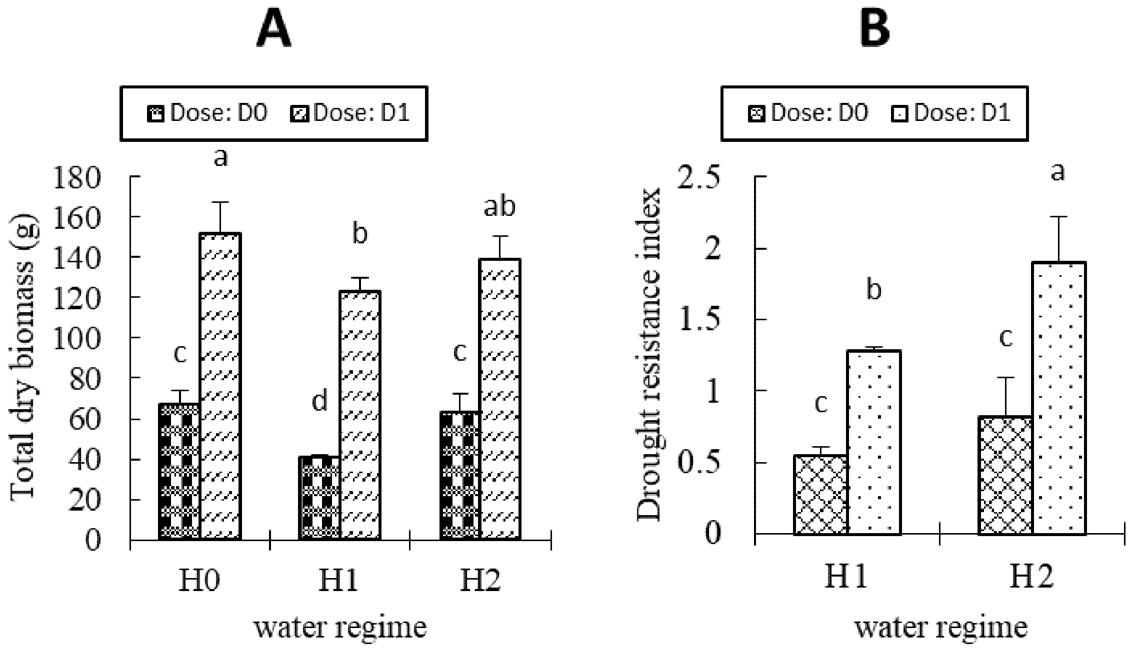

Figure 4. Total dry biomass (A) and drought resistance index (B) of plants grown under water regime and fertilized with laying hen droppings.

stages and fertilized (H1D1, H2D1) increased compared with that of plants not subjected to water deficit and not fertilized (H0D0). However, the dry biomass of plants subjected to water deficit at the vegetative stage and unfertilized showed a reduction compared with those not subjected to water deficit and unfertilized (H0D0). Under water deficit conditions at vegetative stage and 50% flowering, the total dry biomass of fertilized plants (H1D1, H2D1) was higher than that of unfertilized plants (H1D0, H2D0). The water deficit applied at the vegetative stage had a major impact on total biomass, with a 25.43% reduction in total biomass compared with that of the water deficit applied at the 50% flowering stage (Figure 4 A). Analysis of variance showed that fertilization (*P* = 0.000) and water regime (*P* = 0.019) significantly affected total plant dry biomass. However, the interaction of water regime and fertilization had no significant impact on total plant dry biomass (*P* = 0.59).

As shown in Figure 4B, the drought resistance index of plants subjected to water deficit at the vegetative or 50% flowering stage and fertilized (H1D1, H2D1) is higher than that of plants subjected to water deficit at the vegetative or flowering stage and not fertilized (H1D0, H2D0). Plants subjected to water deficit at the 50% flowering stage (H2) had a higher drought resistance index than those subjected to water deficit at the vegetative stage (H1). The results of the analysis of variance revealed a significant effect of fertilization (*P* = 0.000) and water regime (*P* = 0.008) on the drought resistance index, while the interaction of fertilization and water regime did not significantly affect the drought resistance index (*P* = 0.2).

DISCUSSION

Water deficit and fertilization with laying hen droppings had variable effects on the various parameters measured. The water deficit applied during the vegetative stage to unfertilized plants resulted in a reduction in plant height. This decrease in height could be attributed to the decline in soil moisture caused by the suspension of watering, subsequently affecting the plants' water and mineral nutrition. This reduction in water and mineral nutrition likely decreased the plant's metabolic activities, leading to a slowdown in plant growth. According to Kapoor et al. (2020), water stress causes an alteration in mitosis, elongation and cell multiplication in plants, resulting in reduced growth. However, water deficit combined with fertilization resulted in a significant increase in plant height. The positive response of plant height to the combined effect of water deficit and fertilization could be explained by the increased availability of nutrients provided by droppings. According to Moreno et al. (2019) and Dimkpa et al. (2020), organic fertilizers modulate the mobility and availability of nutrients under different soil water regimes, thereby improving plant growth. Thus, 0.55 g of phosphorus and 1.62 g of N supplied per plant through fertilization would have stimulated plant growth. According to Harper (1994), P and N are essential macronutrients for plants, promoting growth, especially in younger plants. K (0.2 mg/plant) supplied to plants through fertilization would have mitigated the effect of water deficit on plant height. Indeed, under water deficit conditions, K improves water uptake and does not alter apoplasmic water flow (Fournier et al*.,* 2005; Grzebisz et al*.,* 2013), has a positive effect on transpiration (Brag, 1972; Lindhauer, 1985; Zain and Ismail, 2016) and counteracts the negative effects of abscisic acid (Peuke et al*.,* 2002). Of the 2 water deficit application periods, the one applied at the vegetative stage was highly detrimental to plant height growth. This can be explained by the fact that the plants are young and still growing, in contrast to the 50% flowering stage when plant height growth is complete. Similar results were observed on cowpea (Farouk and Amany, 2012) and basil (Pirbalouti et al., 2017).

The water deficit imposed on unfertilized plants at the vegetative or 50% flowering stage had no significant effect on the number of tillers produced per plant. The absence of a significant effect of water deficit on tillering can be explained by the period of application of the water deficit. The first water deficit was applied on 14th days after sowing (DAS), by which time tillering had already begun 4 days earlier, on 10th DAS. The second water deficit was applied at the 50% flowering stage, by which time tillering had also finished. But water stress combined with fertilization improved plant tillering. This improvement in tillering could be explained by the positive effect of fertilization, which improved the supply of nutrients to the plants. In terms of nutrient requirements for millet during tillering, N is the highest, indicating its predominant role during tillering. Fertilization provided 1.62 g of N per plant, and this availability of N would have stimulated plant tillering.

In contrast to the number of tillers produced per plant, the water deficit imposed on unfertilized plants at the 50% flowering stage reduced the number of tillers that were flowering per plant. This reduction is thought to be due to the lack of water in the soil for the plants, which limited the flowering of the tillers. In fact, water deficit reduces water nutrition, mineral nutrition, transpiration and carbon dioxide uptake in plants, resulting in reduced photosynthesis. It should be noted that at the flowering stage, most of the products of photosynthesis or photo-assimilates are destined for flowering and seed production. Photo-assimilates are therefore in short supply, reducing the number of flowering tillers. Similar results have been observed in barley (Lawlor et al., 1981) and wheat (Imran et al*.,* 2020). However, water deficit applied at the vegetative stage to unfertilized plants had no effect on the number of flowering tillers. On the one hand, this may be explained by the fact that tillers due to flower later were not sensitive to the water deficit imposed at the vegetative stage. On the other hand, this is due to the period of application of the water deficit (juvenile stage), which has very little effect on flowering. The water deficit combined with fertilization favored an increase in the number of flowering tillers. This increase in the number of flowering tillers can be explained by the production of a greater number of tillers per plant and the earlier flowering of fertilized plants. Indeed, the main stems and tillers began flowering earlier. On the other hand, the availability of K (0.2 mg/plant) improved water nutrition while reducing the adverse effect of water deficit, thus promoting better phosphorus and nitrogen uptake. This improved mineral and water nutrition optimized photosynthesis, resulting in an increase in the number of flowering tillers.

The ear weight of unfertilized plants subjected to water deficit at the 50% flowering stage decreased significantly. The reduction in ear weight can be explained by a reduction in the number of ears produced by the plants, a reduction in ear length and diameter, spikelet abortion and poor filling of millet spikes due to lack of water in the soil. Similar results have been observed in wheat (M'Barek and Mounir, 1991). The application of fertilizer to stressed plants led to an increase in ear weight. This was due to the beneficial effect of fertilization in making nutrients available. The availability of nutrients stimulated ear growth and an increase in fertile tillers.

The water deficit imposed at the 50% flowering stage reduced the GW of both unfertilized and fertilized plants. In fact, the water deficit cancelled out the effect of fertilization on GW, so that there was no difference between the GW of stressed, unfertilized plants (H2D0) and that of stressed, fertilized plants (H2D1). The good vegetative development of the fertilized plants increased their need for water, and as they produced more ears, the water stress imposed meant that the plants did not have the quantity of water required to ensure grain filling, and therefore the transfer of photo-assimilates to the ears. The lack of water and photo-assimilates in the panicles would cause spikelet abortion and poor ear filling. Similar results were observed in millet (Siéné et al*.,* 2016), sunflower (Khodaei-joghan et al*.,* 2018), sorghum (Ibrahim et al*.,* 2019) and wheat (Imran et al*.,* 2020). The GW of fertilized plants subjected to water deficit at the vegetative stage was higher than that of control plants. This result can be explained on the one hand by the period of application of the water deficit. In fact, the water deficit applied at the vegetative stage had no repercussions on flowering and ear filling. On the other hand, this can be explained by better photosynthetic activity due to good water and mineral nutrition. The photo-assimilates produced by photosynthesis favored better development and filling of the ears. Similar results were observed in wheat (Imran et al*.,* 2020).

The total dry biomass of unfertilized plants was significantly reduced by the water deficit applied at the vegetative stage. The reduction in dry biomass was due to low resistance to water deficit, poor tillering and a slowdown in stem and leaf growth induced by lack of water in the soil. However, water deficit combined with fertilization (H1D1, H2D1) significantly increased total dry biomass. The increase in biomass can be explained by fertilization, which made nutrients available, thereby increasing the plants' drought resistance index. These nutrients improved plant height, leaf growth and tillering. Water deficit applied at the 50% flowering stage was more detrimental to plant yield parameters. The best performance under water deficit conditions was recorded in fertilized plants.

Conclusion

The aim of this study was to evaluate the impact of laying hen droppings on millet growth and production under water deficit conditions. The results showed that water deficit, when applied during the vegetative stage to unfertilized plants, led to a reduction in plant height, total dry biomass, and the drought resistance index. However, in the case of fertilized plants subjected to water deficit at the vegetative stage, there was an increase in height, the number of tillers produced, the number of flowering tillers, ear and grain weight, total dry biomass, and the drought resistance index. Water deficit applied at the 50% flowering stage resulted in a reduction in the number of flowering tillers, spike weight, and grain weight for unfertilized plants, as well as grain weight for fertilized plants. Conversely, there was an improvement in height, the number of tillers produced, the number of flowering tillers, spike weight, total dry biomass, and the drought resistance index in plants subjected to water deficit at the 50% flowering stage when they were fertilized. Of the two water deficits (H1 and H2), only the water deficit applied at the 50% flowering stage had a negative impact on the yield parameters of unfertilized plants (ear weight, grain weight, and total dry biomass) and fertilized plants (grain weight). The trends in the results indicate that fertilization with laying hen droppings appears to be beneficial in crop environments subject to pockets of drought, especially during the vegetative stage.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Amadou I, Gounga ME, Le GW (2013). Millets: Nutritional composition, some health benefits and processing. A review. Emirates Journal of Food and Agriculture 25:501-508.

Bekoye BM (2011). Caractérisation chimique et minérale des grains de mil [*Pennisetum glaucum* (L .) R . Br .] de Côte d ' Ivoire. International Journal of Biological and Chemical Sciences 5(5):2039-2044.

Brag H (1972). The influence of potassium on the transpiration rate and stomatal opening in *Triticum aestivum* and *Pisum sativum*. Physiology Plant 26:250-257.

Dakheel AJ, Shabbir G, Al-Gailani AQ (2009). Yield stability of pearl millet genotypes under irrigation with different salinity levels. Europ JSR 37:288-301.

Diallo D, Tamini Z, Barry B, Faya AO (2010). Effet de la fumure organique sur la croissance et le rendement du riz Nerica (WAB 450 IBP 28HB) à Faranah. International Journal of Biological and Chemical Sciences 4(6):2017-2025.

Dimkpa CO, Fugice J, Singh U, Lewis TD (2020). Development of fertilizers for enhanced nitrogen use efficiency-Trends and perspectives. Science Total Environment 731:139113.

Dreyer H (2018). Comité De L' Agriculture. Proposition relative à la célébration d'une Année internationale du mil, pp. 1-9

Drugmand J (2020). Impact des stress thermique et hydrique sur la croissance, la reproduction et la pollinisation de *Fagopyrum esculentum* et comparaison de la pollinisation chez deux espèces de *Fagopyrum* 100.

FAOSTAT (2020). Rendement du mil au Burkina Faso. https://www.fao.org/faostat/fr/#data/QCL, october 15th

FAOSTAT (2022). Rendement des céréales au Burkina Faso. https://www.fao.org/faostat/fr/#data/QCL, December 21th

Farouk S, Amany AR (2012). Improving growth and yield of cowpea by foliar application of chitosan under water stress. Egypt JB 14:14-16.

Fournier JM, Roldãn AM, Sãnchez C, Alexandre G, Benlloch M (2005). K+ starvation increases water uptake in whole sunflower plants. Plant Science 168:823-829.

Ghannoum O (2009). C4 photosynthesis and water stress. Annals of Botany 103:635-644.

Grzebisz W, Gransee A, Szczepaniak W, Diatta J (2013). The effects of potassium fertilization on water-use efficiency in crop plants. Journal of Plant Nutrition and Soil Science 176:355-374.

Hamadou M, Idrissa S, Mahamadou C, Oumarou S, Valentin K (2017). Potentialités fourragères du mil (*Pennisetum glaucum* (L .) R . Br) : Revue de littérature. Journal of Animal and Plant Sciences 34(2):5424-5447.

Hayano-Kanashiro C, Calderon-Vazquez C, Ibarra-Laclette E, Herrera-Estrella L, Simpson J (2009). Analysis of gene expression and physiological responses in three Mexican maize landraces under drought stress and recovery irrigation. PLoS ONE 4:7531-7531.

Hanane S (2013). Le pouvoir antioxydant des polyphénols de l'espèce *Pennisetum glaucum* (millet) du sud de l'Algérie, Université Abou Bakr Belkaid Tlemcen, Algérie. https:// www.fao.org/faostat/fr/♯data/QCL. 04-07-2023.

Harper JE (1994). Nitrogen metabolism. Physiology and determination of crop yield. Boote KJ(Eds), pp. 285-302.

Ibrahim ME, Abd El-Aty MI Ahmed RAT, Taia AAM (2019). Combined Effect of Poultry Manure and Soil Mulching on Soil Properties, Physiological Responses, Yields and Water-use Efficiencies of Sorghum Plants under Water Stress, Communications in Soil Science and Plant Analysis. DOI: 10.1080/00103624.2019.1671445

Imran H, Muhammad ASR, Rashid I, Muhammad UA, Muhammad HR, Shameem R, Muhammad TK, Muhammad MA, Muhammad W, Salman A (2020). Potential effects of biochar application on mitigating the drought stress implications on wheat (*Triticum aestivum* L.) under various growth stages. Journal of Saudi Chemical Society 24(12):974-981. https://doi.org/10.1016/j.jscs.2020.10.005

Kapoor D, Bhardwaj S, Landi M, Sharma A, Ramakrishnan M, Sharma A (2020). The Impact of Drought in plant metabolism: How to exploit tolerance mechanisms to increase crop production. Applied Sciences 10(16):5692.

Konaté B, Nana R, Nana L S, Badiel B, Sawadogo M, Tamini Z (2016). Morphophysiological response of okra [*Abelmoschus esculentus* (L.) Moench] subjected to biofertilization and water stresses. International Journal of Biological and Chemical Sciences 10(5):2108-2122.

Khodaei-joghan A, Gholamhoseini M, Agha-alikhani M, Habibzadeh F (2018). Response of sunflower to organic and chemical fertilizers in different drought stress conditions. Acta Agriculturae Slovenica pp. 271-284. https://doi.org/10.14720/aas.2018.111.2.03

Lawlor DW, Day W, Johnston AE, Legg BJ, Parkinson KJ (1981). Growth of spring barley under drought: crop development, photosynthesis, dry-matter accumulation and nutrient content. The Journal of Agricultural Science 96:167-186

Lindhauer MG (1985). Influence of K nutritional drought on water relations and growth of sunflower (*Helianthus annuus* L.). Z. Pflanzenernächr Bodenk 148:654-669.

M'Barek BN, Mounir NMS (1991). Effet d'un déficit hydrique, survenant à différents stades de développement du blé, sur l'humidité du sol, la physiologie de la plante et sur les composantes du rendement. Méditerranée 2:53-60.

Maiti R, Rodríguez HG (2010). Pearl millet: potential alternative for grain and forage for livestock in semi-arid regions of Mexico. International Journal of Bio-resource and Stress Management 1:45-47.

Moreno-Jiménez E, Plaza C, Saiz H, Manzano R, Flagmeier M, Maestre FT (2019). Aridity and reduced soil micronutrient availability in global drylands. Nature Sustainability 2:371-377.

Newman Y, Jennings E, Vendramini J, Blount A (2010). Pearl millet (*Pennisetum glaucum*): overview and management. University of FL. IFAS Extension.

Peuke AD, Jeschke WD, Hartung W (2002). Flows of elements, ions and abscissic acid in Ricinus communis and site of nitrate reduction under potassium limitation. Journal of Experimental Botany 53:241-250.

Pinheiro C, Chaves MM (2011). Photosynthesis and drought: can we make metabolic connections from available data. Journal of Experimental Botany 62:869-882.

Pirbalouti AG, Malekpoor F, Salimi A, Golparvar A (2017). Exogenous application of chitosan on biochemical and physiological characteristics, phenolic content and antioxidant activity of two species of basil (*Ocimum ciliatum* and *Ocimum basilicum*) under reduced irrigation. Scientia Horticulturae 217:114-122

Shelke GV, Chavan AM (2010). Improvement of agronomically desirable genotypes for downy mildew disease resistance in Pearl millet [*Pennisetum glaucum* (L.) R. Br.] By recombination breeding. Journal of Ecobiotechnology 2(1):16-20.

Sory A, Nana R, Banhoro A, Ouedraogo WIC, Sawadogo M (2022). Millet (*Pennisetum glaucum* (l.) R. Br.) Productivity under fertilization with poultry droppings in BURKINA FASO. International Journal of Agriculture, Environment and Bioresearch 7(6):269-282.

Siéné AL, Doumbouya C, Traore M, Condé MS, N'Guettia VMT, Kone M (2020). Effet de quatre types de fertilisants sur la croissance et la productivité de deux génotypes de maïs (*Zea mays* L .) en cas d ' un semis tardif à Korhogo au Centre- Nord de la Côte d ' Ivoire pp. 55-68.

Siéné C, Ambroise L (2016). Evaluation of water stress impact on growth and yield of millet (*Pennisetum glaucum* (L .) R . Br .) for two nitrogen fertilization conditions in a semi-arid tropical environment. International Journal of Innovation and Applied Studies 14(3):779-789.

Wahid BA, Abdellah B (2020). Qualités nutritionnelles de millet perlé. Mémoire P 58.

Zain NAM, Ismail MR (2016). Effects of potassium rates and types on growth, leaf gas exchange., & biochemical changes in rice (*Oryza sativa*). – Agricultural Water Management 164(1):83-90.