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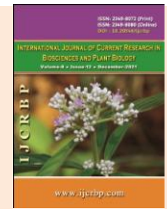

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Supplemental irrigation frequencies effects on the morphological and yield parameters of mung bean [*Vigna radiata* (L.) R. Wilczek] in Burkina Faso

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Abstract

Mung bean (*Vigna radiata*) is grown throughout the world thanks to its short cycle, its great adaptability to climatic conditions and its good digestibility. In Burkina Faso, agriculture is faced with irregular rainfalls, resulting in water stress on plants causing growth and yields reduction. This study aims at identifying supplemental irrigation frequencies that help good mung bean plant to grow and yield. So, four watering schemes were applied to plants aged 26 days, grown in pots on a sandy and silty substrate, in natural conditions of light and temperature during the wet season. The watering regimes concerned a batch of plants watered only by rain (0 day scheme) and three other batches, each watered with tap water in the absence of rain respectively every 5 days, every 10 days and every 15 days. A completely randomized three-replicate block system was set up and agro-morphology parameters were measured. The study showed that the 5 days diet resulted in plants with better growth and good pod yields compared to other watering schemes. These results confirm that supplemental irrigation applied early during drought po0063kets is resilience to the irregularity of rains in the wet season, which is accentuated by climate change.

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Introduction

In Burkina Faso, 49% of rural families do not manage to produce or obtain sufficient food to meet their needs (FAO, 2011) and their vulnerability remains despite the latest attempts to diversify cropping practices (Badiel et al., 2017). Climate models predict that climate change due to greenhouse gas emissions from deforestation, industrialization and urbanization will do droughts more frequent and more intense (Collins et al., 2008; Salack et al., 2011; Wittig et al., 2007), with more dramatic consequences for agriculture and food security in developing countries (IPCC, 2007; Yang et al., 2010). Farmers will therefore have to deal with disturbances in the spatio-temporal distribution of rains.

To cope with the random fluctuations in rainfall and therefore in crop yields, farmers have resorted to both traditional techniques and those developed by agricultural research centers. These techniques include the use of short-cycle varieties which can accommodate a shorter rainy season. This is the case with the mung bean (*Vigna radiata* (L.) R. Wilczek), a short-cycle leguminous plant of the Fabaceae family. The plant contains a major source of minerals and dietary protein for urban and rural populations and their livestock in the tropics of Africa, Asia, and America (Sahoo et al., 2003). It is used in food crop for its seeds and leaves which are eaten and highly appreciated for their good digestibility and the absence of flatulence. Mung bean has antifungal, antibacterial (Wang et al., 2006) and hypoglycemic effects with high antioxidant activity (Mohanty et al., 2000).

However, using short-cycle crop varieties nowadays has some limits which can be explained on the one hand by a high uncertainty on starting and ending dates of rainy season and by the appearance of drought pockets during the wet season, on the other hand. It is therefore necessary to develop methods that enable better adaptation of short-cycle varieties to drought pockets more frequent and persistent. It is in this perspective of resilience to climate change that supplemental irrigation for the improvement of cultivation techniques is applied to the cultivation of mung bean in our study.

This study aims at assessing the effects of different supplemental irrigation schemes on the morphological parameters in the vegetative and post-flowering phases and on the agronomic parameters of mung bean plants.

Materials and methods

Study site

The experiment was carried out within the UFR / SVT (Training and Research Unit in Earth and Life Science) of the University Joseph KI- ZERBO in Ouagadougou from August to November 2019. The experimental plot is located at an altitude of 319 m, at latitude 12 ° 22 '45.6' 'north and longitude 001 ° 29' 52.3 '' west. The test was carried out under natural conditions of lighting, temperature, humidity and rainfall, in a Sudano-Sahelian climate. The temperature average was 31.52±2.57°C and relative humidity average was 65.51±6.39% during the test.

Plant material

The study was focused on the short-cycle variety of mungbean called Beng Tigré. The seeds were provided by the national research program on annual oil and leguminous seed plants at INERA (Institute for the Environment and Agricultural Research National Research). This variety is native to the Indian subcontinent. It has an erect or semi-erect stem. It flowers from the 30th to the 70th day after sowing. Its growth is determined. Its leaves and seeds are dark green and green, respectively.

Experimental device

The adopted experimental set-up is in fully randomized blocks with three replicates. Each block or replicate consists of 36 pots including 09 pots per experimental unit with 4 levels of applied water treatment: a supplemental irrigation after 5 days of no rain (5 D), a 10 days' supplemental irrigation (10 D) and a 15 days' supplemental irrigation (15 D). The control plants were watered only by rain which corresponds to the 0-day irrigation (0 D). A total of 108 pots were used (1 variety × 4 water treatment levels × 3 replicates × 9 pots per experimental unit) according to the experimental setup.

Carrying out the test

Sowing was carried out at the rate of five seeds per pot containing a sandy and silty growing substrate (3.92% of clay, 21.57% of silt and 74.51% of sand) taken from a natural formation of the Gampela in Soudano-Sahelian zone. Fourteen days after sowing, seedlings were removed for having one plant per pot. Supplemental irrigation schemes were applied in the study depending of the drought pocket duration during the rainy season. They consisted in a supply with one liter of tap water in case of no rain. So; the 5-days' regime or 5D is a supply of water every 5 days; the 10-days' regime or 10D for every 10 days and the 15-days' regime or 15D for every 15 days. Pots watered on the 0-day regime or 0D were not concerned with supplemental irrigation; they were watered only by rain until the end of the experiment. Data were collected from all the 108 plants from the 26th DAS (day after sowing), the date on which the application of the different watering schemes started. During the treatments (from 26th to 80th DAS) and at their end (80th DAS), morphological parameters have been measured. Agronomic parameters were only measured at the test end. Because of certain parameters to be measured at the test end, each plant has been out rooted and sectioned at the crown into shoot and to root parts.

Measuring morphological parameters

The height of the plants (HT): For the measurements, a decameter was used from the neck to the apex of the main stem of the plant, every 03 days from the 26th day after sowing (DAS) to the test end (80 DAS).

Number of leaves (NL) and leaf area (LA): The leaves were also counted every 03 days from 26 DAS to the end of the test. The leaf area (LA) in cm2 of the plants was measured using the CI-202 device (Laser Leaf Area Meter - CI-202 by CID Bio-Science, Inc.). The CI-202 is used to measure plant leaves, placing the leaf on the pallet and sliding the scanner along the leaf.

Number of nodules (Nb nod): Separating the roots from the nodules consisted of submerging the root system of each plant in a container with clear tap water to remove the soil from the roots and the nodules. Once the roots and the nodules separated from the soil, the nodules were dried with filter paper and then manually counted.

Fresh and dry root biomasses (FRB and DRB), and fresh and dry shoot biomasses (FSB and DSB): After the roots and nodules were separated from the soil in the water container, roots were dried with filter paper and with shoot parts were weighed to determine their fresh biomass, FRB and FSB respectively. Fresh biomasses were then dried on laboratory work surfaces before drying them for 24 hours into an oven set at 80°C for dry shoot (DSB) and root (DRB) biomasses obtaining.

Measuring agronomic parameters

Number of pods per plant (PN): Pod harvesting was gradual and was carried out on all plants. The count was done manually.

The dry pods mass per plant (DPM): The harvested pods were dried on a work surface in the laboratory and then weighed. This parameter is expressed in grams (g).

Statistical analyses: Average calculations and the graphs were performed using Excel spreadsheet. Averages were subjected to an analysis of variance (ANOVA) and comparison tests were carried out according to Student Newman-Keuls with the significance level determined at the probability threshold of 0.05. All these analyses were carried out with the GENSTAT DISCOVERY software.

Results

Morphological parameters of shoot part

Plant height

Fig. 1 shows the evolution curves in plants height under different watering regimes. During the first 47 days after sowing, the height increased steadily and similarly for all treatments. From 50 DAS, only the height growth curve of plants under 5D treatment continued differently. At the end of the test at 80 JAS, the average height of the plants under the different treatments varied from 27.36±0.76 to 36.25±1.16 cm. The difference between these heights was very significant: the highest plants were obtained with the 5D regime and the smallest plants from the other watering schemes (P <0.001; Table 1).

Leaves number and area

The leaves number produced by the plants according to the watering schemes evolved gradually and in a similar way from 26 and 53 DAS (Fig. 2). From 56 DAS, a highly significant difference has been noted between the 5D treatment and the others in the average number of leaves. From 62 DAS, the 10D regime was also different from the rest. At the end of the test, the number of leaves in the 5D treatment was greater than that of 10D which was greater than those of 15D and 0D (P <0.001; Table 1). The irrigation schemes 0D and 15D generated the lowest and same number of leaves throughout the duration of the test (Table 1).

The leaf area of plants under 5D treatment is significantly higher (P <0.001) than that of other supplemental irrigation schemes (Fig. 3). In fact, under 5D regime, plants had the main leaf area comparatively to plants watered only by rain or by other water regimes (P <0.001; Table 1).

Fresh and dry shoot biomasses (FSB and DSB)

The fresh and dry shoot biomasses of the plants were significantly different depending on the supplemental watering schemes applied (P <0.001; Table 2). Indeed, the plants under 5D regime had more FSB or DSB than plants under other treatments. For fresh biomass, 0D regime led to the lowest average while 10D and 15D led to plants with similar averages. For dry biomass, plants under 10D, 15D and 0D had the same average (Table 2).

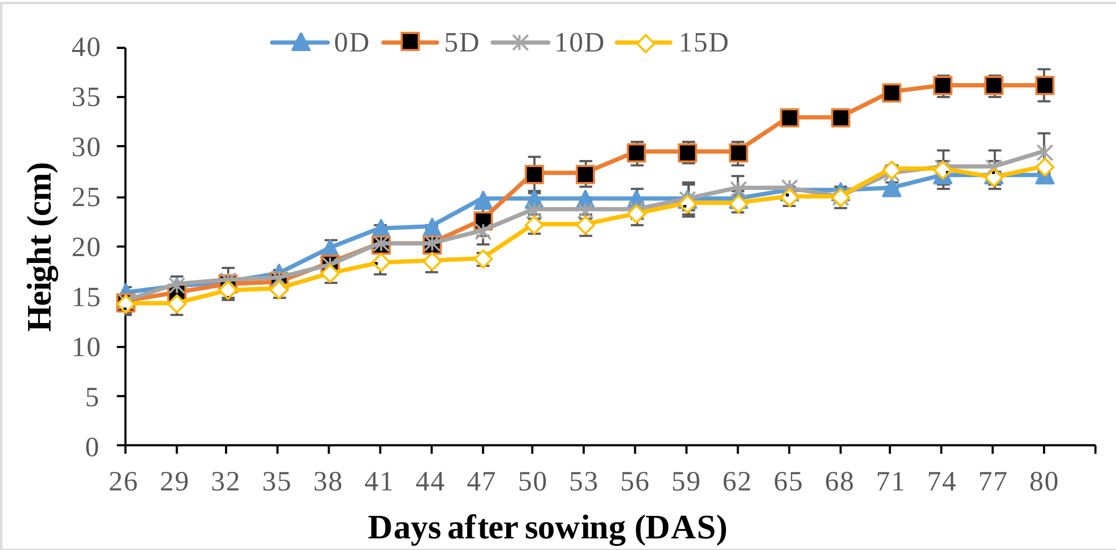

Fig. 1: Evolution curve of the plant height. 5D = watering every 5 days; 10D = watering every 10 days; 15D = watering every 15 days; 0D = no supplemental watering.

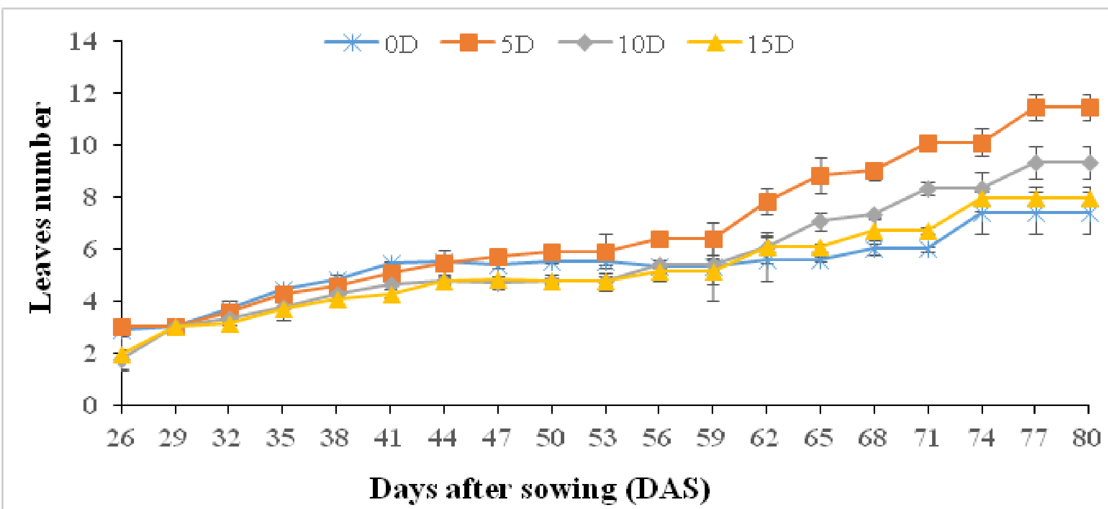

Fig. 2: Evolution curve of plant leaves. 5D = watering every 5 days; 10D = watering every 10 days; 15D = watering every 15 days; 0D = no supplemental watering.

Table 1. Height and number of leaves of plants under different watering regime at 80 DAS.

Watering regime		0D	5D	10D	15D	*P*
Parameter	HT	27.36±0.76[b]	36.25±1.16[a]	29.42±1.30[b]	28.53±0.10[b]	*<0.001*
	NF	7.39±0.64[c]	11.44±0.42[a]	9.33±0.49[b]	7.94±0.39[c]	*<0.001*

HT: plant height; NL: leaves number of plants. 5D = watering every 5 days; 10D = watering every 10 days; 15D = watering every 15 days; 0D = no supplemental watering. P: probability. Values with the same letter in the same row are not significantly different at the 5% level.

Table 2. Fresh shoot biomass, dry shoot biomass, fresh root biomass and dry root biomass of plants under different watering regimes.

Parameter		FSB	DSB	FRB	DRB
Watering regimes	0D	4.34±0.10[c]	1.69±0.13[b]	4.26±0.03[b]	1.38±0.10[b]
	5D	21.05±1.53[a]	4.00±0.74[a]	13.01±2.46[a]	3.00±0.29[a]
	10D	9.27±0.60[b]	2.10±0.10[b]	5.92±0.68[b]	1.25±0.25b
	15D	7.63±1.22[b]	1.59±0.35[b]	4.11±0.84[b]	1.56±0.10[b]
	P	*<0.001*	*<0.001*	*<0.001*	*<0.001*

FSB: fresh shoot biomass; DSB: dry shot biomass; FRB: fresh root biomass; DRB: dry root biomass; 5D = watering every 5 days; 10D = watering every 10 days; 15D = watering every 15 days; 0D = no supplemental watering. P: probability. The values with the same letter at the level of each column are not significantly different according to the Newman-Keuls test at the 5% level.

Table 3. Yield components under the influence of irrigation regime.

Parameter		NP	DPM (g)
Watering regimes	0D	5.39±0.34[b]	2.94±0.29[b]
	5D	10.22±0.55[a]	5.52±0.39[a]
	10D	6.44±0.55[b]	3.52±0.75[b]
	15D	5.67±0.14[b]	3.19±0.26[b]
	P	*0.001*	*0.002*

NP: number of pods; DPM: dry pod mass. 5D = watering every 5 days; 10D = watering every 10 days; 15D = watering every 15 days; 0D = no supplemental watering. P: probability. The values with the same letter at the level of each column are not significantly different according to the Newman-Keuls test at the 5% level.

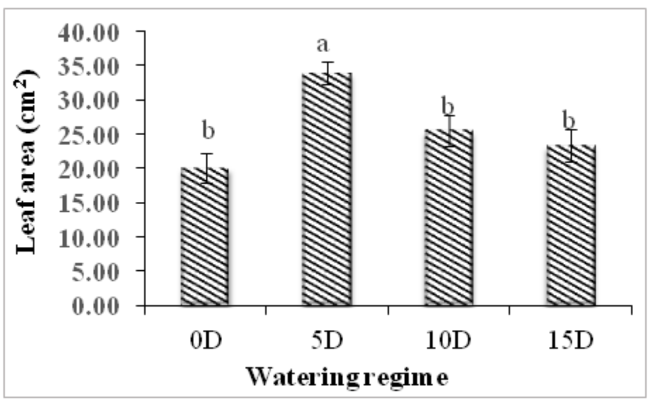

Fig. 3: Leaf area of plants according to watering regimes. 5D = watering every 5 days; 10D = watering every 10 days; 15D = watering every 15 days; 0D = no supplemental watering. Histograms with the same letter do not differ from each other at the 5% level.

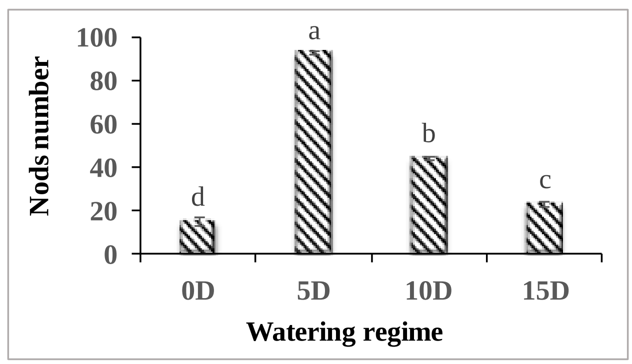

Fig. 4: Nodules number in mung bean plants according to watering regimes. 5D = watering every 5 days; 10D = watering every 10 days; 15D = watering every 15 days; 0D = no supplemental watering. Histograms with the same letter do not differ from each other at the 5% level.

Morphological parameters of root part

Number of nodules

The average number of nodules of plants watered every 5D (92.83 ± 0.68 nodules) is significantly and respectively higher than that of plants watered every 10D (44.17 ± 0.95 nodules), every 15D (23.00 ± 1.36 nodules) and only by rain 0D (14.92 ± 2.11 nodules) (P <0.001; Fig. 4).

Fresh and dry root biomass (FRB and DRB)

For fresh or dry root biomass, the highest averages were obtained under the 5D regime. The other treatments led to plant with the same root biomass (P <0.001; Table 2).

Agronomic parameters

Number of pods per plant (NG)

A significant difference in the number of pods, depending on the frequency of supplemental irrigation was observed (P <0.001; Table 3). At 80 DAS, plants under 5D had almost doubled the pods number of 0 day watered plants (P <0.001; Table 3).

Dry pod mass per plant (DPM)

Likewise, a significant difference in dry pod mass when different frequencies of supplemental irrigation are considered (P = 0.002; Table 3). Only plants grown with 5D regime showed a different average, the highest, from those under other treatments.

Discussion

Water supply is one of the key environmental factors for agricultural production. Water is the major constituent of the cell and therefore the crucial element for the proper functioning of plants. The high number of nodules of the plants under the 5D regime and their high root biomass could be explained by the fact that this watering frequency would provide the root cells with water permanently. The irrigation water, which is also a source of oxygen, also contributes to lowering the temperature of the soil, a favorable condition for metabolism, root growth and nodules functioning. Kihindo et al., 2016 observed a high root biomass and a high nodules number in cowpea varieties respectively KN1 and KVx61.1 watered every 2 days (Kihindo et al., 2016). Such watering conditions would allow the proper functioning of the rhizobia in the mobilization of atmospheric nitrogen as an essential mineral element for the synthesis of assimilates involved in pod production and grain filling. Our results also corroborate those of Dhole and Reddy, (2010) on mung bean, who reported that the roots number per plant decreases with decreasing water potential or with increasing water deficit (Dhole and Reddy, 2010). Similar findings were reported by Shihab et al., 2013 who observed increased production of root biomass from irrigated mung bean plants compared to non-irrigated (control) plants (Shihab et al., 2013). In our study, plants under 0D, 10D and 15D watering schemes, however, had low production of root biomass. These watering schemes would have reduced the water supply to plants, causing a decrease in total biomass as observed in cowpea, sesame and soybean (Badiel et al., 2017; Kaboré et al., 2011; Kihindo et al., 2016).

According to our study, the shoot part growth parameters (number of leaves, the height of the plants, the leaf area and the aerial biomass (fresh or dry) showed significant differences considering water regimes. The 5D scheme led to the tallest plants, the highest number of leaves produced, the highest leaf area and biomass. Even if 10D and 15D regimes did not improve the FRB, they however increased the number of nodules (3 times and 1.5 times more respectively compared to 0D) which could result in a better seed yield later. Also, it seems that depending on the frequency of supplemental irrigation, root production can be improved (case of DRB under 5D), unchanged (at 10D) in favor of the formed nodules. Under the 0D, 10D and 15D treatments, the similar values obtained for the stem height, leaf area or dry aerial biomass parameter attest that these parameters were not under water supply influence. However, the lowest fresh shoot biomass observed under 0D regime testifies to a greater water content in the shoot part of the plants under 10D and 15D schemes: the supplemental irrigation frequencies 10 and 15D would improve the water status of the plant and mainly in shoot. This low aerial biomass is believed to be due to a slowdown in growth which may be explained by the decrease in turgor in the tissues, one of the components of the water potential, necessary for cell expansion. The biosynthesis of cell walls as well as the mechanisms of cell division would be rapidly altered. Ultimately, the limitation of vigor would ultimately lead to a reduction in evaporating surfaces and / or senescence of the leaves which would, however, occur at higher parching levels. The 5 days watering scheme, which caused more rhizogenesis, would have favored good water mobilization and the drainage of nutrients necessary for the growth of the whole plant. Deficient watering schemes can be perceived as water stress for the plant causing changes in the internal functioning of plants including a reduction in height, diameter at the root neck and total dry biomass of sesame under water deficit conditions (Compaoré, 2011; Hassanzadeh et al., 2009; Kihindo et al., 2016; Shihab et al., 2013; Tantawy et al., 2007).

The highest number of pods and the highest dry pod mass of plants under 5D treatment could be explained by the fact that this added water would ensure better absorption of mineral elements, favoring a significant production of photoassimilates, which could be considered as raw material for pod production. On the contrary a water deficit due to a long drought pocket (0D regime) or by insufficient irrigation (10D and 15D) would cause a reduction in photosynthesis, therefore a reduction in the translocation of assimilates for the formation of pods, hence the lowest productivity (almost 2 twice less the number or the dry pods weight). Blum and Pnuel (1996) reported that water stress acts negatively on the synthesis of assimilates and / or on their transfer (Blum and Pnuel, 1990). Similar findings obtained by Shihab et al. (2013) on mungbean, indicated that stressed plants produced fewer pods (Shihab et al., 2013).

Conclusions

A regular water supply during mung bean cultivation is one of the essential conditions for good pod yield. This study revealed a strong influence of supplemental irrigation every 5 days during drought pockets on growth parameters and productivity of mung bean. The importance of leaves number, biomass, nodules number, and pods number under this watering regime presages that it could be integrated into the cultural resilience practices when faced with irregular rainfalls observed during the wet season and accentuated by climate change.

Conflict of interest statement

Authors declare that they have no conflict of interest.

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