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Evaluation of *Vigna subterranea* (L.) Verdc. development under different mounding periods in Viçosa, MG, Brazil

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ABSTRACT

The bambara bean (*Vigna subterranea* (L.) Verdc.) is native to the African continent, being considered rustic, tolerant to water stress, high temperatures, and soils with low fertility. In view of climate change, it's a strategic crop having a short cycle and a fast economic return. The practice of mounding is considered essential for crops that have parts of economic interest below the soil surface promoting better plant development, protection against solar radiation and weed control. The objective of this work was to evaluate the phytotechnical aspects of bambara bean under different periods of mounding. The methodology used was a randomized block design with three treatments and six repetitions submitted to the Tukey test at 5% probability. The treatments were no mounding (SA), mounding 60 days after planting (A60AP), and mounding 90 days after planting (A90AP). The parameters analyzed were mass of 100 seeds (M100S), number of seeds per plot (NSP), productivity in kg/ha (PR), and number of seeds per kilo (NSQ). The results pointed out that mounding brings positive results for M100S and PR for A60AP. A90AP and SA had reductions in M100S and increase in NSQ when compared to A60AP. The variable NSP was not influenced by any of the treatments. Thereby, A60AP lead to a greater increase in productivity and quality for bambara groundnut in region of MG, Brazil.

Keywords: Agroecology, Climate change, Crop care, Underutilized species.

Avaliação do desenvolvimento de Vigna subterranea (l.) verdc. sob diferentes períodos de amontoa em Viçosa, MG, Brasil

RESUMO

O feijão-bambara (*Vigna subterranea* (L.) Verdc.) é uma planta nativa do continente africano, sendo considerada rústica, tolerante ao déficit hídrico, altas temperaturas e solos de baixa fertilidade. Tendo em vista um cenário de mudanças climáticas, é indicada como uma planta estratégica devido a possuir ciclo curto, permitindo rápido retorno econômico. A amontoa é essencial para plantas que se desenvolvem abaixo da superfície do solo, promovendo melhor desenvolvimento, proteção contra radiação solar e controle de plantas daninhas. Objetivou-se avaliar os aspectos fitotécnicos da cultura sob diferentes períodos de amontoa. O delineamento utilizado foi em blocos ao acaso com três tratamentos e seis repetições, submetidos ao teste de Tukey (p-valor = 0,05). Os tratamentos foram Sem Amontoa (SA), Amontoa 60 Dias Após Plantio (A60AP) e Amontoa 90 Dias Após Plantio (A90AP). Os parâmetros analisados foram a massa de 100 sementes (M100S), número de sementes por parcela (NSP), produtividade em kg/ha (PR) e número de sementes por quilo (NSQ). Houve aumento de M100S e PR para A60AP. A90AP e SA tiveram reduções na M100S e aumento no NSQ comparado a A60AP. A variável NSP não foi influenciada pelos tratamentos. Em suma, A60AP promoveu aumento na qualidade e produtividade para o feijão-bambara na região de Viçosa, MG, Brasil.

Palavras-chave: Agroecologia, Espécies subutilizadas, Mudanças climáticas, Tratos culturais.

1. Introduction

Climate change can be perceived today as having several impacts on the environment and especially in agriculture. Therefore, in order to mitigate these impacts, transformations in food practices and in its production chain are necessary (Mesquita and Bursztyn, 2018). According to Vianna et al. (2013), the process of adaptation to climatological transformations includes the introduction of new species adapted to extreme variations, such as strong waves of high and low temperatures and that have good resilience. Thus, plants of economic interest that develop below the soil surface are interesting alternatives, and practices, such as mounding, that provide better development of these plants, should be carried out in order to obtain higher yields.

The practice of mounding consists of bringing a portion of soil closer to the basal part of the plants in order to promote better development of the underground organs and protection against solar radiation, as well as controlling weeds in the planting line and avoiding competition (Lopes and Buso, 1999). The bambara bean (*Vigna subterranea* (L.) Verdc.) still has its center of origin undefined, but some studies point out that its center of origin is the central region of Mali and the two centers of diversity are, in Africa from the northeastern region of Nigeria to the northern region of Cameroon, and in Asia, covering Sri Lanka, Malaysia, the Philippines and India (Majola et al., 2021).

The name "Bambara" comes from an ethnic group of the same name living in West Africa, and the plant is used not only in agriculture, but also has influence in cultural aspects, such being used in funeral rituals, the birth of twins, and also in medicine, to treat nausea and motion sickness in pregnant women, to cure diarrhea, preventing high blood pressure and treat epilepsy (Anchirinah et al., 2001; Esan et al., 2023). It is a plant belonging to the botanical family Fabaceae, characterized by having symbiotic associations with bacteria of the genus *Bradyrrhizobium* sp. that promote biological nitrogen fixation (Puozaa et al., 2017). In addition, the plant belongs to the genus *Vigna* sp., characterized by its great socioeconomic importance where it is widespread, as for the species of the same genus, such as the chickpea (*Vigna unguiculata* (L.) Walp.) that has great importance in Brazil (Pahane et al., 2017; Melo et al., 2022).

For being native to the African continent, the bambara bean is considered a rustic plant that presents interesting characteristics for the current scenario of brazilian agriculture, especially with regard to semi-arid regions and for family farming, such as a short cycle promoting a faster economic return, resistance to drought, development in low fertility soils, tolerance to high temperatures, and the possibility of consortia and crop rotation (Anchirinah et al., 2001; Department of Agriculture, 2016). In addition, it is a crop that has high nutritional value, about 60% carbohydrates, 21% proteins and 6,5% lipids, and has uses as forage, animal feed, processed and *in natura* (Pahane et al., 2017).

Commonly used by the population in the African continent, bambara bean is a neglected and underutilized crop worldwide, possessing great agronomic potential in terms of food security and being more resilient in view of climate change being less nutritionally demanding, more tolerant to pest and disease attack and higher yield under the same soil and climate conditions compared to peanut (*Arachis hypogaea* L.) (Heller et al., 1997; Collinson et al., 1999).

Although it has all these interesting characteristics, the bambara groundnut has not yet been tested in Brazil. In this way, the conduction of researches and the establishment of techniques that favor the plant understanding and behavior must be carried out and implemented in order to increase the production and quality. Thus, the objective of this work was to define which is the best period of mounding, that favors the behavior of the species in order to improve and increase the production and quality of bambara beans.

2. Material and Methods

The study was carried out between February and September of 2021 at the Experimental Campus Horta Velha, belonging to the Federal University of Viçosa, Viçosa, Minas Gerais, Brazil (20º45'28.39" S, 42º50'44.82" W) in a total area of 111.44 m^2. The area has been used for over 20 years by undergraduate and post graduate students to conduct experiments, with a common incidence of pests and diseases, and evidences of a compacted soil, as surface crust and angled lumps of soil.

The design used was a randomized block design, composed of two groups of three blocks (ABC, DEF) with three treatments and three repetitions in each group, totaling six repetitions per treatment (Figure 1). The treatments were no mounding (SA), mounding 60 days after planting (A60AP), and mounding 90 days after planting (A90AP). Each block consisted of 35 plants, with 15 plants considered useful for the analysis. The spacing was 0.2 m between plants and 0.6 m between rows. The analyzed variables were productivity in kg/ha (PR), mass of 100 seeds in grams (M100S), number of seeds per kilo (NSQ) and number of seeds per portion (NSP). The methodology for the analysis were conducted after the harvest, 171 days after sowing, which was done manually with the aid of a hoe. The harvest was defined at the moment when the pods became wrinkled and had a brownish color (Figures 4c and 4d), indicating that they were mature and ready for harvest. The analysis for mass was executed by weighing in a precision balance and the productivity was calculated using the number of plants in a row, its spacing and calculated the number of plants per hectare.

According to the soil analysis (Table 1), for fertilization 60g of bovine manure was used per planting hole in order to supply the amount of phosphorus necessary for the implementation of. The soil fertility standard was defined following the recommendations described in the book "5th Approximation: Recommendations for the use of correctives and fertilizers in Minas Gerais" developed by the Soil Fertility Commission of the State of Minas Gerais (Ribeiro et al., 1999).

According to its properties, it can be classified as a clay soil with 58.2% of clay, 30.5% of sand and 11.2% of silt. The irrigation was performed by bamboo-tutored microsprinklers covering the entire area homogeneously. To evaluate the effect of mounding on the variables, the data obtained was submitted to statistical analysis using the statistical software SISVAR Version 5.8 (Build 92), performing the F test and Tukey's test at a 5% probability level.

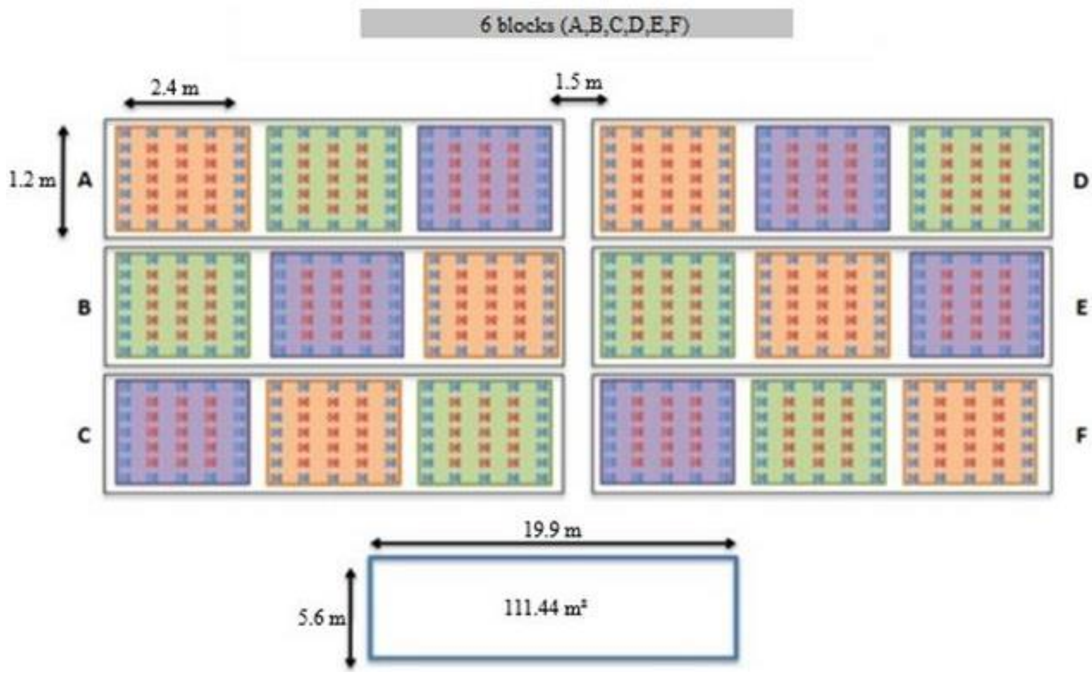

Figure 1. Randomized blocks design for the experiment in Federal University of Viçosa, Viçosa, MG, Brazil

Figure 2. Experimental area where the research was conducted in Campus Experimental Horta Velha – Universidade Federal de Viçosa, Viçosa, MG, Brazil.

Table 1. Results of soil analysis from Campus Experimental Horta Velha – Universidade Federal de Viçosa, Viçosa, MG, Brazil.

Soil Depth	pH H2O	P mg/dm³	K mg/dm³	Ca^{2+} cmolc/dm³	Mg^{2+} cmolc/dm³	S mg/dm³	B mg/dm³	Cu mg/dm³	Mn mg/dm³	Fe mg/dm³
0 - 20	6.45	115.40	187.00	5.11	1.36	3.00	0.95	9.54	75.10	83.50
20 - 40	5.83	56.90	157.00	3.99	1.00	17.60	1.09	7.66	54.80	80.80

Soil Depth	Zn cmolc/dm³	Al^{3+} cmolc/dm³	H^{+}+Al^{3+} cmolc/dm³	SB cmolc/dm³	t cmolc/dm³	T cmolc/dm³	V %	m %	P-rem mg/L	OM dag/kg
0 - 20	7.45	0.00	3.20	6.95	6.95	10.15	68.50	0.00	30.90	2.66
20 - 40	4.56	0.00	3.70	5.39	5.39	9.09	59.30	0.00	26.50	2.13

3. Results and Discussion

Ouédraogo et al. (2012) reported that mounding is realized by farmers who claim to obtain higher yields, during different periods. Ntundu et al. (2006) confirms the use of this practice by local producers in Tanzania and the same is stated by Brink et al. (2006) and Hasan et al. (2018) in Botswana. When analyzing the productivity variable, as described in Table 2, the statistical analyses demonstrated a significant difference for the PR variable in the A60AP treatment, showing 602.1 kg/ha and differed statistically from the other two treatments, SA and A90AP, which showed 466.7 kg/ha and 483.6 kg/ha, respectively.

This can be evidenced by the greater volume of soil provided by mounding in the pod maturation stage, allowing greater seed growth, as well as the reduction of physical interference during the flowering (Figure 3b) and development period (Figure 3a), a time when the reproductive organ is more fragile and can easily break with the minimal impact. It can be affirmed that the mounding when performed 60 days after planting brought positive aspects to productivity.

Khan et al. (2021) report that in localities where bambara beans are grown, productivity is relatively low (650–850 kg/ha) due to the lack of cultural techniques that promote better crop development. According to Fatimah et al. (2018), bambara beans can reach yields of up to 4.000 kg/ha if cultivated in optimal conditions. The low production of bambara beans in this experiment are results from the adversities of the area where the experiment has been conducted mentioned above and the late date of sowing.

During the development of the bambara bean there was an incidence of the fungus *Cercospora* sp. causing leaf spots and consequently reducing the photosynthetic area, which may have reduced the production of pods from the replacement of leaves by root reserves (Pittner et al., 2016). The onset of the pathogen may have occurred due to late planting associated with microsprinkler irrigation. For this, 0.5% Bordeaux syrup, a copper fungicide, was applied weekly for 12 weeks. Sesay et al. (2008) reports that the planting date affects significantly the development of bambara groundnut, compromising its yield attesting that the earlier sowing date can reduce the yield by up to 75%.

As reported by Ouédraogo et al. (2013), in semi-arid regions the mounding must be done in 14 or 49 days after sowing (DAS), avoiding coinciding with the flowering period that is about to 33±5 days after sowing. The author obtained an increase of 108% and 201% for seed yield while performing mounding in 14 and 49 DAS, respectively, while compared to the mounding at 28 DAS. The present experiment obtained similar results while performing the mounding at 60 DAS. For the variable mass of 100 seeds, that can be observed in Table 2, there were significant differences among all treatments.

In the A60AP treatment, a higher M100S was obtained, probably from the better development of the underground organs caused by the mounding in this period, promoting an increase of 16.50% compared to the SA treatment. When compared with treatment A90AP, A60AP had an increase of 7.02%. The results obtained in this work are similar to the results obtained by Mhungu and Chiteka (2010), where the mounding at 60 days after planting also showed an increase in productivity.

Table 2. Average comparison table for productivity (PR) and mass of 100 seeds (M100S) - Viçosa, MG, Brazil.

Treatment	Productivity (kg/ha)	
A60AP	602.10	a
A90AP	483.60	b
SA	466.70	b
Averages	517.50	
Treatment	Mass of 100 seeds (g)	
A60AP	54.90	a
A90AP	51.30	b
SA	47.10	c
Averages	51.10	

Averages followed by the same letter do not differ from each other, according to Tukey test ($p \leq 0.05$). SA = no mounding; A60AP = mounding 60 days after planting and A90AP = mounding 90 days after planting.

However, they disagree with the reduction of this variable for A90AP. Ouédraogo et al. (2012) showed that mounding at seven weeks after sowing promotes greater pod development and greater grain fulfillment by obtaining higher seed weight, length and 100 seeds weight in comparison to mounding at two weeks after sowing, promoting a higher yield. Significant differences were observed for the variable Number of Seeds per Kilo, as according with the data described in Table 3, for the NSQ variable, the three treatments also differed from each other.

Because of the better seed development in A60AP, this treatment obtained a lower number of seeds per kilo, with a value close to 1,820 seeds. The treatment with the highest number of seeds per kilo was SA, with an amount close to 2,125 seeds, since according to the data obtained, this treatment had the lowest mass per 100 seeds. The greater number of seeds for this variable may have occurred due to the lower development of the pods caused by the reduction of the soil volume in the period of development of the seeds, reducing their growth space and consequently originating smaller seeds.

Brink et al. (2006) reported that mounding is used to obtain higher yields and is combined with weeding control confirming the beneficial effects and the importance of this cultural treatment for the culture of bambara beans. According to Mubaiwa et al. (2018) the practice of mounding is essential in its cultivation but is very laborious in relation to cowpea.

Table 3. Average comparison table for variables number of seeds per kilo (NSQ) and number of seeds per portion (NSP) – Viçosa, MG, Brazil.

Treatment	Nr. of seeds/kg	
A60AP	1821.04	c
A90AP	1949.99	b
SA	2124.25	a
Averages	51.10	
Treatment	Nr. of seeds/portion	
A60AP	190.30	a
A90AP	174.70	a
SA	179.17	a
Averages	181.39	

Averages followed by the same letter do not differ from each other, according to Tukey test ($p \leq 0.05$). SA = no mounding; A60AP = mounding 60 days after planting and A90AP = mounding 90 days after planting.

Figure 3. Vegetative (a) and flowering (b) stages of Bambara beans in Campus Experimental Horta Velha – UFV, Viçosa, MG, Brazil.

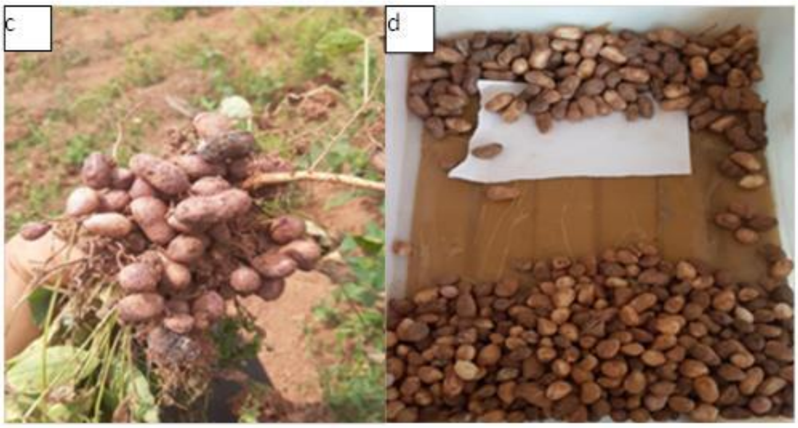

Figure 4. Unique plant (c) and experimental parcel (d) of bambara beans collected in Campus Experimental Horta Velha – UFV, Viçosa, MG, Brazil.

By being a plant with similar reproductive organs, it can be attested by Thilini et al. (2019) that mounding at 37 days in groundnut (*Arachis hypogaea* L.) caused a higher value for the variable hundred seeds weight, fresh weight of pods per plant, shelling percentage and yield and it is used by farmers who aims for a higher yield. Finally, for the variable NSP, it can be inferred from the data obtained that mounding did not influence any of the treatments studied (Table 3). The number of seeds did not change with the mounding technique, since promoting a larger volume of soil is directly related to the development of the pods and not to the production of flowers of the plant. The different mounding periods did not interfere positively or negatively with the number of seeds per plot.

4. Conclusions

It can be concluded that the mounding can avoid unwanted plants and when performed at 60 days after planting, promoted better development of the underground organs, increasing the mass of the seeds and consequently favoring the increase in productivity of bambara beans. Due to the increase in seed mass, mounding at 60 days resulted in a reduction in the number of seeds per kilo compared to the other two treatments. The number of seeds per portion did not vary and was not influenced by any of the mounding periods tested. Furthermore, the importance of further research related to bambara beans is highlighted in order to develop the best management practices to obtain better yields and incorporate the crop as an option in Brazil.

Authors' Contribution

Filipe Cassimiro Magalhães de Paula conducted the research for the undergraduate thesis that later became this article, participating in the planning, implementation, data collection, and analysis. Tomaz Ribeiro Lanza supervised the planning, implementation, data collection, and analysis. Gustavo Franco de Castro reviewed the composition and structure of the article and discussed the data analysis. Lin Chau Ming assisted in the implementation of the work by providing the seeds and techniques for growth.

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