

EVALUATION OF GROWTH AND YIELD PERFORMANCE OF SESAME (*SESAMUM INDICUM* L.) LANDRACES UNDER VARYING PLANTING DATES

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Summary

This study explored how sowing dates impact development, phenology, and yield of sesame, an important oilseed crop with substantial nutritional, economic, and livelihood value to Zimbabwe's smallholder farmers. The study addresses the persistent issue of low sesame productivity, a problem driven by erratic rainfall patterns from climate change and a shortage of agronomic advice on optimal planting times. Our field study was conducted in Chiundura Communal Area, using a 3×2 factorial arrangement in a Randomized Complete Block Design. The study compared three planting dates (late October, late November, and late December) across two local landraces, Black and White seeded. Results clearly demonstrated that planting date was the most significant factor ($p < 0.05$) affecting all growth and yield metrics; differences between the two landrace were negligible. Sowing early in late October produced the most favorable results, yielding the tallest plants, the quickest time to flowering and maturity, and the highest yields (893.3 kg/ha for Black and 898.0 kg/ha for White sesame). Conversely, later plantings resulted in extended phenological durations, reduced seed weight, and dramatic yield declines of up to 50%. These outcomes are explained by crops facing diminishing soil moisture levels and exposure to suboptimal temperatures during the critical reproductive stages, which constrained flowering and seed filling. The distinctive contribution of the study lies in providing statistically validated, local evidence for an optimal sesame planting window. Our practical, climate-smart recommendation is to sow sesame by the end of October to maximize yields, build resilience to climate variability, and strengthen the crop's economic success in marginal agro-ecosystems.

Keywords: marginal agro-ecosystems, phenological growth, planting dates, sesame landraces, yield.

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1. Introduction

One of the oldest domesticated oil crops in the world is sesame (*Sesamum indicum* L.), which archeological evidence data dates back to more than 5,500 years ago [1]. It still enjoys

great agronomic, nutritional, and economic values in the tropical and subtropical areas, due to its exceptional ability to adapt to drought-prone conditions, and its adaptability to be grown under low-input systems [2–4]. The crop is well known as a climate smart crop [5, 6] since it is resistant to heat stress, able to work well in marginalized soils and may well be incorporated into climate smart agricultural systems to help in enhancing sustainability and resilience of the smallholder farmer.

The nutritional profile of sesame seeds is characterized by the elevated oil (50–60%) and protein (18–25%) contents [7] and high levels of such minerals as calcium, phosphorus and iron [8, 9], natural antioxidants like sesamin and sesamol [10]. These features render sesame a valuable crop in human diet [11] as well as find use in pharmaceuticals, health foods and cosmetics thereby making it a commercially viable and cash crop with increased international demand. Sesame can be used in a dual manner in sub-Saharan Africa as both a subsistence crop and an export product that is highly valued to diversify the economy. It provides a cheap point of entry into commercial agriculture to many smallholder farmers since it requires fewer inputs to give competitive returns against staple cereals like maize and sorghum.

However, in spite of these strengths, the production of sesame in Zimbabwe is underdeveloped due to unpredictability in climatic conditions, paucity of research and lack of uniformity in agronomic processes. The unpredictable nature of rainfall and its abrupt end, together with the use of outdated recommendations about planting between the middle of December and February have also led to the frequent failure of crops and failure in yields. In this case, the germination rate will decrease [12], the growth of plants will be slowed down [13]. Moreover, poor knowledge of farmers on the best time to plant, how to manage the soil fertility and the pests further increases inefficiency in production. The problems are magnified by low market connections, variable price volatility, and competition by food security crops, none of which augurs well in the potential of sesame to transform agricultural practices to sustainable levels.

The planting date is one of the most important factors that define the performance of sesame and affect the development of phenological, biomass accumulation, and reproductive success. Research in other areas has identified that early planting can be used to realize more out of the available soil moisture, vegetative growth, and production of more capsules and achieve better yields [14–16]. On the other hand, late sowing reduces the duration of growth cycle, exposes plants to terminal drought and decreases the amount and quality of seeds [17, 18]. Nevertheless, even with increased attention to climate adaptation and resilience, Zimbabwe does not have data at the local level on the optimization of planting of sesame in the different agroecological zones [19].

The research thus aims at establishing the impact of different planting dates on the growth and yield performance of *Sesamum indicum* when under Zimbabwe field conditions. The study aims at developing evidence-based solutions to boost climate-resilient and sustainable sesame production, the livelihoods of smallholder farmers, and the role of the crop in the national food security and climate-resilient crops production. This study, by filling in the available knowledge gap, will help make traditional forms of farming consistent with the current, adaptive approaches that are needed to make agricultural systems resilient and market focused.

2. Materials and methods

2. 1. Study site description

The experiment was done in Chiundura communal area in the Midlands Province of Zimbabwe. The area is characterized by hot, dry weather with average annual rainfall of 600 mm per year that impairs the production of several crops. It has altitude of 1282 m above sea level and mean temperature ranges of 18–24°C. The physiochemical properties of the soil at the experimental site are characteristic as shown in **Table 1**.

Table 1

Physiochemical properties of the soil at the experimental site

Parameter	Status
Soil	Clay loam
EC	0.14–0.68 dS·m ⁻¹
pH	7.24–7.75
Calcareous [CaCO ₃]	9.5%
Organic content	0.62–0.86%
Total N content	0.03–0.06%
Available P	6.8–9.2 mg·kg ⁻¹
Extractable K	60–110 mg·kg ⁻¹

2. 2. Experimental design and treatments

The experimental design used was a 2x3 factorial treatment structure arranged in a randomized complete block design (RCBD) and replicated three times. Two sesame landrace varieties (*V*) were investigated against three planting dates (*D*) as shown in **Table 2**.

Table 2

Description of experimental treatments used

Factors	Description
Planting date (<i>D</i>)	
<i>D</i> ₁	31 October planting
<i>D</i> ₂	30 November planting
<i>D</i> ₃	31 December planting
Sesame variety (<i>V</i>)	
<i>V</i> _{white}	White landrace sesame variety
<i>V</i> _{black}	Black landrace sesame variety

2. 3. Experimental procedure

The experimental units were 5 m long and 3.2 m wide. In the treatment plots, there were 8 rows of plants with an interrow spacing of 0.4 meters. Preparation of land was done by plowing then a garden rake was used to create finely aggregated soil surface in the areas where a plant was to be planted. To assure uniformity in all treatment plots, Compound D fertilizer (N7-P14-K7) was applied uniformly to all treatment plots prior to the raking procedure at the rate of 200 kg/ha and then worked into the soil during the raking process. Planting lines were carefully laid out on the basis of a stake and string system. The rate of seeding used was 3 kg/ha. There was later nutrient supplementing as topdressing with nitrogen (34.5% N) in two applications; one at 3 weeks after emergence of 50 kg/ha and another at six weeks. Manual weed control was done by the use of hoes so that the plots would not have any serious weed competition during crop cycle. The experimental period did not have any economically significant pest or disease infestations.

2. 4. Data collection

For each treatment, data were collected from 10 plants methodically chosen from the 8 central rows. Measurements of growth parameters were done in the fresh biomass:

1. Final plant height. It was taken just before harvesting the measurement was taken using a ruler. This was measured from the base to the tip of the plant.
2. Pod clearance. It was obtained prior to harvesting before drying and threshing. A ruler was used to measure pod clearance of the tagged plans per plot.
3. Days to 50% flowering. A given stage was registered when observable 50% of the crop was in flower and the day in terms of number of days from planting was noted.
4. Days to physiological maturity. Days from planting were registered when the plant leaves, stems, and capsules begin to turn yellow and the lower leaves of the plant start shedding.

5. Number of seeds capsule⁻¹. At maturity, the capsules from the randomly selected plants were threshed and number of seeds in each capsule was counted and averaged.

6. Seed weight per capsule⁻¹. A total of 20 capsules were taken and threshed to obtain seed. Average seed weight was obtained by dividing the weight obtained from the 20 capsules by 20 to get seed weight per capsule.

7. Biological yield. At maturity, the sesame crop in each plot was harvested; weighed and biological yield was converted to kg/ha.

8. Harvest index. Harvest index is the ratio between seed yield and biological yield. Harvest index (%) was calculated by the following formula

$$\text{Harvest index (HI)} = \frac{\text{Seed yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100. \quad (1)$$

9. Yield. The weight was obtained after harvesting when the crop has been dried, threshed and weighed in grams per plot and then converted to express in tons per hectare.

2. 5. Data analysis

Data collected was subjected to analysis of variance (ANOVA) using GenStat statistical package version 18 while the mean separation was carried out using the least significant difference (LSD) technique at 5% significant level.

3. Results

3. 1. Effect of planting date and variety on plant height

The interaction between *D* and *V* was not statistically significant ($p > 0.05$). However, an analysis of the data revealed that planting dates had a significant impact on plant height ($p < 0.05$), as detailed in **Table 3**. Specifically, delaying the crop's planting time led to a reduction in plant height. The latest planting date (*D*₃) yielded the shortest plants, measuring 47.47 cm. The variety employed, in contrast, did not demonstrate any significant effect on plant height.

Table 3

Plant height, pod clearance, days to 50% flowering and physiological maturity as affected by planting date and variety

Treatment	Height (cm)	Pod clearance (cm)	50% flowering (days)	Physiological maturity (days)
Date (<i>D</i>)				
<i>D</i> ₁	64.23 ^c	10.38 ^c	45.67 ^a	92.00 ^a
<i>D</i> ₂	55.43 ^b	8.52 ^b	54.00 ^b	116.67 ^b
<i>D</i> ₃	47.47 ^a	5.52 ^a	57.83 ^c	124.83 ^c
LSD _{0.05}	2.182	0.547	1.389	4.966
Variety (<i>V</i>)				
<i>V</i> _{black}	55.79 ^z	8.21 ^z	52.78 ^z	112.67 ^z
<i>V</i> _{white}	55.63 ^z	8.07 ^z	52.22 ^z	109.67 ^z
Mean	55.71	8.14	52.50	111.17
LSD _{0.05}	1.782	0.447	1.135	4.054
CV _%	3.0	5.2	2.1	3.5
Interactions				
<i>D</i> * <i>V</i>	ns	ns	ns	Ns

Note: ns denotes non-statistical significance.

3. 2. Effect of planting date and variety on pod clearance

Analysis shows that the timing of planting was an important factor influencing pod clearance ($p < 0.05$). In contrast, neither the specific sesame variety chosen ($p > 0.05$) nor the interaction between *D* and *V* had a significant effect on this measurement. Sowing at the earliest date produced

the greatest pod clearance for both the V_{black} (10.47 cm) and V_{white} (10.30 cm) varieties, a result that was statistically significant ($p < 0.05$) compared to other timings. Conversely, delaying planting to the final date yielded the lowest pod clearance observed across all landraces (Table 3).

3. 3. Effect of planting date and variety on number of days to 50% flowering

The findings show that the time it took for sesame to reach 50% flowering was significantly affected by its establishment date ($p < 0.05$), but not by the specific variety used ($p > 0.05$). The study also found no evidence that the effect of the planting date depended on the variety, as their interaction was not significant ($p > 0.05$). Furthermore, plants established earliest (D_1) flowered the quickest, whereas those established last (D_3) took the longest, requiring up to 57.83 days to reach this stage (Table 3).

3. 4. Effect of planting date and variety on number of days to physiological maturity

The analysis shows that crop establishment date (D) and variety (V) influenced the time to physiological maturity independently, with no significant interaction effect between them ($p > 0.05$). The establishment date was the primary driver of this outcome but variety, on its own, had no discernible impact on the maturation timeline ($p > 0.05$). Notably, crops planted at the latest date took the longest to mature (124.83 days). In contrast, the earliest planting (D_1) significantly shortened this period to 92.00 days ($p < 0.05$) (Table 3).

3. 5. Effect of planting date and variety on Seed capsule⁻¹

The analysis found no significant interaction between $D \times V$ in determining the number of seeds per capsule ($p > 0.05$). However, when looking at each factor on its own, planting date was key influence on seed count ($p < 0.05$), while the specific plant variety was not ($p > 0.05$). Planting earlier proved to be most effective with the first planting date (D_1) yielding an average of 64.23 seeds per capsule. In contrast, later plantings (D_2 and D_3) registered significantly fewer seeds at 55.43 and 47.47, respectively, both falling below the overall study average of 55.71 seeds per capsule (Table 4).

Table 4

Seeds capsule⁻¹, seed weight (g), biological yield (kg/ha) and harvest index (%) as affected by planting date and variety

Treatment	Seeds capsule ⁻¹	Seed weight (g)	Biological yield (kg/ha)	Harvest index (%)
Date (D)				
D_1	64.23 ^c	10.38 ^c	2875 ^c	30.99 ^c
D_2	55.43 ^b	8.52 ^b	2604 ^b	24.08 ^b
D_3	47.47 ^a	5.52 ^a	2308 ^a	19.99 ^a
LSD _{0.05}	2.182	0.547	81.8	1.961
Variety (V)				
V_{black}	55.79 ^z	8.21 ^z	2597 ^z	24.42 ^z
V_{white}	55.63 ^z	8.07 ^z	2594 ^z	25.61 ^z
Mean	55.71	8.14	2596	25.02
LSD _{0.05}	1.782	0.447	66.8	1.601
CV _%	3.0	5.2	2.4	6.1
Interactions				
$D*V$	Ns	Ns	Ns	Ns

Note: ns denotes non-statistical significance.

3. 6. Effect of planting date and variety on 1000 seed weight

Analysis shows no significant interaction between $D \times V$ regarding their combined effect on seed weight ($p > 0.05$). However, planting date by itself was a key determinant of 1000-seed weight ($p < 0.05$). The earliest sowing date (D_1) resulted in the heaviest seeds at 10.38 g, and re-

corded a consistent decrease in weight as planting was delayed. Conversely, the specific variety chosen did not significantly influence seed weight ($p > 0.05$), implying that all varieties performed similarly in this regard across the different planting times (Table 4).

3. 7. Effect of planting date and variety on biological yield

Statistical analysis shows no significant interaction between $D \times V$ in their effect on biological yield ($p > 0.05$) (Table 4). However, the planting date itself was a significant factor influencing sesame total biomass ($p < 0.05$). The choice of variety, on the other hand, did not significantly alter the yield ($p > 0.05$). The advantage of early sowing was clear with crops established at the beginning of the season producing considerably a higher biological yield. The landrace V_{white} and V_{black} achieved 2,894 kg/ha and 2,856 kg/ha respectively, considerably more than the yield from the latest plantings, which fell to just 2,308 kg/ha.

3. 8. Effect of planting date and variety on harvest index

The harvest index was significantly influenced by the planting date ($p < 0.05$), but not by the sesame variety ($p > 0.05$). The analysis results show a no significant interaction between these two variables ($p > 0.05$). The initial planting date (D_1) proved optimal, achieving the highest harvest index values for both V_{black} (31.10%) and V_{white} (30.87%) landraces. In sharp contrast, the final planting date (D_3) produced the lowest recorded indices, which were 19.03% and 20.94% for V_{black} and V_{white} respectively (Table 4).

3. 9. Effect of planting date and variety on final yield of sesame

These results indicate that planting date significantly influenced sesame seed yield, with its effect being consistent across both landraces tested (Fig. 1). The earliest planting (D_1) generated the highest yields for V_{black} (888.3 kg/ha) and V_{white} (893.3 kg/ha). Delayed planting to the final date, however, substantially reduced yields to 445.7 kg/ha and 476.7 kg/ha, respectively. Analysis showed no combined effect of planting date and variety, and the mean yields of the V_{black} and V_{white} varieties were statistically comparable ($p > 0.05$).

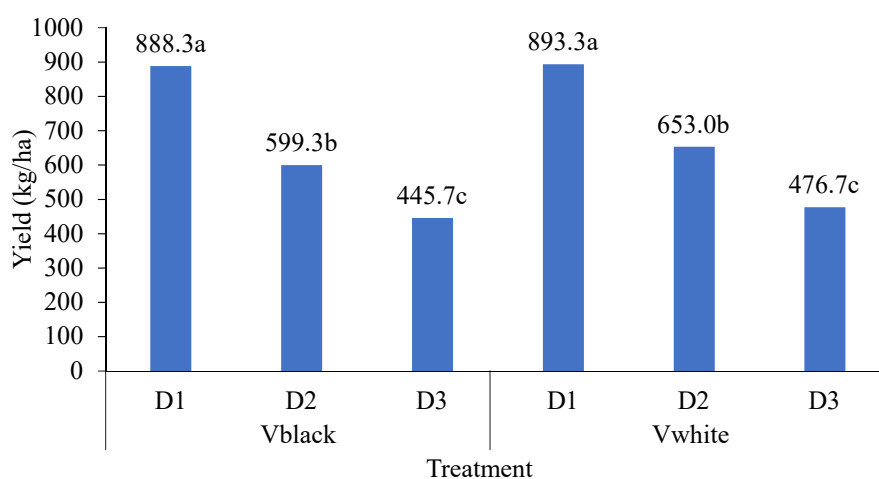


Fig. 1. Yield of sesame as affected by planting date and variety

4. Discussion

Out of all the sources of impact, the outcomes of the research clearly show that the planting date is the number one determinant of sesame performance. Only this variable controlled the development of the plant (the phenological growth and accumulation of biomass and final yield). On the other hand, the decision between the V_{black} and V_{white} local landrace varieties did not generate any statistically significant differences in these results. This finding is further reinforced by the fact that there was no significant interaction effect meaning that both varieties responded equal-

ly when there was a change in the planting schedules. Our result provides evidence in favour of the hypothesis of [20] that the genetic foundation of important agronomic characteristics of many African sesame landraces can be constrained, perhaps due to convergent evolution in response to similar environments.

The effect of sowing date on the height of sesame plant seems to be derived directly on the effect of temperature and photoperiod on vegetative growth. The initially-sown plants (D_1) were likely in optimum conditions to produce gibberellin, a hormone that is recognized to stimulate stem-extension and hence the difference in height is easy to understand [21]. Plants planted late in the season (D_3) in turn were subjected to lower night temperatures and lower daylight. These conditions are known to inhibit auxin movements, which is one of the basic mechanisms of cell expansion, hence limiting growth [22]. The real impact of this environmental influence was seen in our data which reported a distinct decrease in the average height of the plants in 64.23 cm (D_1) to 47.47 cm (D_3). Such findings are also consistent with other studies in semi-arid areas which also prove that delayed sowing reduces the vegetative period and exposes the crop to more environmental stress and ultimately reduces the plant vigor.

The late sowing of sesame meant that the plants grew shorter, hence having the pods more in contact with the ground. This was due to the fact that the plants received a shorter time in vegetation growth before they had flowered. Cold weather and a late start reduced the extent of stem lengthening and limited the number of branches and thus made the plant fail to establish a solid canopy. This is unlike an early planting, which is advantageous to the indeterminate growth habit of sesame, as it gives it a greater period to form new branches and nodes. Late sowing hastens the onset of the reproductive stage, usually before an adequate structure of stems and leaves is developed [23]. The fact that this response was similar in all local varieties points out to a common and advantageous adaptive mechanism of modifying plant architecture.

The chosen date of sowing controlled the period of time required to reach the 50 percent flowering and physiological maturity of the crops. This dependability is a variable of the cumulative thermal period that the plants had to go through during their development. An example is that the early-sown crops (D_1) gained heat units faster thus 50 percent of flowering was achieved in a mean of 45.67 days. Comparatively, later planted crops took a more time of 57.83 days to cover the same mark. This delays the later-sown crops to this longer developmental period, and may have repressed the expression of important genes that control flowering, including FLOWERING LOCUS T [24, 25].

The postponement of the planting date made the crop life cycle prolonged and the time taken to reach physiological maturity of the crop was 92 days in the first planting (D_1) and around 125 days in the final planting (D_3). These crops that had been sown later had lowered exposure to photosynthetically active radiation (PAR) and had had a narrower range of temperature daily. These conditions have been known to inhibit movement of the energy-rich compounds and decrease the metabolic rate in the seed fill phase [26, 27]. In crops that rely on rainfall, this prolonged growth would introduce a vulnerability so that when the rainy season either stops or there is a late drought the crops would not have enough time to reach full maturity.

The later sowing dates also were related to a decrease in the number of seeds/capsule, and the number of seeds narrowed down to 47.47 in the late plantings (D_3) and 64.23, in the early planting (D_1) group. This reduction is in line with the known effects of heat and moisture stress through the flowering stage, which may reduce the pollen viability and enhance sterility. Specifically, it is also known that sesame pollen activity is impaired at temperatures above 34°C and such a temperature directly suppresses fertilization [28]. The consistency in all the tested landraces in their reaction indicates the existence of a common genetic vulnerability to this type of environmental pressure.

Seed weight also displayed a parallel down trend, as it decreased to 10.38 grams in the D_1 planting to 5.52 grams in the D_3 planting. This is probably because there is less time to develop the seeds and the amount of energy used during the respiration process due to increased night-time temperature [29, 30]. The period of seed filling itself was reduced by 32–24 days [31]. This, as well as the negative influence of heat stress on the activity of sucrose synthase [32, 33], prevents the effective loading of developing seeds with sugars. The final result is the appearance of smaller and light grains [34].

The lateness in planting date led to a huge loss of overall biomass. This was the case since a reduced growing period had a negative impact on the development of canopy resulting in a reduced leaf area index (LAI) and the ability to capture sunlight towards the end of the cycle. Earlier planted crops, on the other hand, had a long vegetative growth, and thus, they absorb more photosynthetically active radiation (PAR) and produce almost 2.9 metric tons per hectare. Late plantings, in comparison was attaining 2.3 metric tons per hectare. The environmental factors added to this yield gap with the photosynthetic activity being further reduced by heat and water stress during the intervals of high vapor pressure deficit [35].

The harvest index or the ratio of harvestable seed to total biomass also showed a characteristic decline. In the case of the D_1 planting, it was approximately 31% but in the case of the D_3 , it was between 19 and 21%. This is an indication of a typical stress response in which the plant diverts its resources outside reproduction and outside the vegetative maintenance [36, 37]. Later planting seems to have impaired the mobilization of nutrients by developing seed pods leading to greater biomass partitioning to stems and leaves instead of seed development. Basically, the decrease in the harvest index is a stress-impaired limitation in the ability of the plant to transform the total growth into reproductive productivity [38, 39].

The timing of when crops are planted is a key determinant of their final seed yield, a conclusion supported by numerous investigations [40–42]. There are huge advantages with the crops planted early in the season and they yield almost twice as much produce as those planted later. In particular, the early sowings had a yield of 888–893 kg/ha whereas the late planting had 445–477 kg/ha. Such a huge reduction in yield is attributed to a chain of adverse effects on the growth and development of the plant [43–45]. Late sowing was observed to produce shorter plants and pods, less flowering time, and less number of seeds, low seed weight and biomass per individual seed. Since the elements affecting yield were the same in the various landrace varieties that were tested, this decrease can only be ascribed to the environmental factors that were posed by a delayed start to the growing season.

5. Conclusion

The study found that there is a high correlation between the sowing date and harvesting of sesame in Zimbabwe. The sooner the planting is done, the more likely sesame will enjoy all the beneficial warmth and sunlight thus canopy grows well and the overall seed yield is higher. Delayed planting on the other hand subjects the crop to unfavorable temperatures and solar radiation causing retarded growth during the vegetative and seed-filled period. The low levels of performance differentiation between the landrace varieties that were tested indicate that new genotypes will be significant in maintaining yields in a more unpredictable climate. The development of breeding programs in the future should be based on the characteristics of increased heat tolerance, flexible development programs, and more predictable seed-setting performance in stress. To adaptive smallholder farmers in Zimbabwe in rain farming, management has remained a viable and an accessible way of managing climate risk through timing of planting.

Conflict of interest

The authors declare that there is no conflict of interest in relation to this paper, as well as the published research results, including the financial aspects of conducting the research, obtaining and using its results, as well as any non-financial personal relationships.

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Data availability

Data will be made available on reasonable request.

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Use of artificial intelligence

The authors declare the use of generative AI in the research and preparation of the manuscript. Tasks delegated to generative AI tools under full human supervision: aid in the linguistic polishing and clarity enhancement of this manuscript. Generative AI tool used: GPT-4.0, Gemini 2.5, Ghost 4.6 Mini.

The authors bear full responsibility for the final manuscript.

Generative AI tools are not credited and are not responsible for the final results.

Declaration submitted by: *Moses Mutetwa*.

Authors' contributions

Moses Mutetwa: Conceptualization (lead), Writing original draft (lead), visualization; **Charity Gudhlanga:** Conceptualization (support), writing original draft, project administration; **Ignatius Chagonda:** Conceptualization (support), writing original draft and editing; **Nomagu-gu Elizabeth Mazilawa:** Writing-review and editing, visualization; **Clapperton Mapwanyire:** Writing-review and editing; **Simbarashe Muzemu:** writing-review, validation, project administration, supervision.

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