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Optimizing pyrethrum planting dates to enhance productivity in a changing climate: A case of southern Highlands in Tanzania

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Abstract

Pyrethrum has excellent potential for growing and industrial production in Tanzania, offering an environmentally friendly alternative to synthetic pesticides and reducing pest and disease incidence without altering the natural balance. Planting date and seeding rate are critical for the productivity of pyrethrum; however, farmers in recent years have been experiencing climate change, resulting in unreliable planting periods. This study seeks to optimize the planting date for increased crop production. The study was conducted in the Umalila Highlands in the Mbeya region, with demonstration plots established in three villages (Iyunga Mapinduzi, Santilya, and Pashungu) and planted at monthly intervals from January to April. A randomized complete block design with three replications was used. The highest flower yield was achieved with early planting dates, particularly in January, with yields progressively decreasing from February to April. Sowing in January produced a yield of approx. 550 kg ha-1, significantly more than the April control with approx. 122 kg ha-1. The survival rate of Pyrethrum plants was highest at about 75% when planted in January and decreased to 72% in February, 67% in March and 57% in April. Pyrethrum planted in January had the most significant plant height, rosette size, and number of stems at all three sites, while April plantings had the worst performance and higher disease scores. Positive correlations were observed between yield and plant traits, such as height, rosette size, and number of stems, with negative correlations between yield and disease scores.

The study shows that planting pyrethrum in January results in the highest flower yields, optimal plant growth, and survival rates, with yields progressively decreasing in the later months and disease incidence increasing. It is recommended that pyrethrum farmers in the southern highlands of Tanzania plan pyrethrum planting in January to maximize yield, plant health, and profitability.

Keywords: Pyrethrum; Pyrethrins; Planting date; Yield components; Yield; Tanzania

1. Introduction

Pyrethrum is a perennial flowering plant from the Tanacetum (formerly Chrysanthemum) cultivated for its insecticidal properties. The active insecticidal compound is known as pyrethrins, extracted from the dried flower heads. Australia, particularly Tasmania, is the world's foremost producer of pyrethrum, surpassing Kenya's production (Pethybridge et al. 2008). In 2018, Tanzania had a pyrethrum production area of 13,941 hectares and produced 7,036 tonnes of dried pyrethrum flowers (Shimira et al., 2021). While global pyrethrum production has fluctuated over the years, it has generally decreased from 1973 to 2022, with the latest reported production being 5,049.45 tonnes. Pyrethrum's natural insecticidal properties make it highly valued and widely used in organic agriculture and household insecticides. Its demand has continued to rise due to its low toxicity to mammals and biodegradability compared to synthetic insecticides (Zeng et al. 2024). Pyrethrum has excellent potential for growing and industrial production in Tanzania,

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offering an environmentally friendly alternative to synthetic pesticides and reducing pest and disease incidence without altering the natural balance.

Several climatic factors influence the sowing date of pyrethrum. Temperature plays a crucial role, as pyrethrum requires a mild climate with moderate temperatures, avoiding extremes that can hinder germination and growth (Shahrajabian et al., 2020). Precipitation is also essential; adequate rainfall or irrigation is required for seed formation and early stages of growth, while excessive moisture can lead to root diseases. The length of the day and the intensity of sunlight are essential for photosynthesis and flower development. The optimal sowing times depend on increasing day length (Suraweera et al. 2020). To ensure successful germination and establishment of seedlings, soil temperature and conditions influenced by climatic factors such as frost and seasonal fluctuations must be considered (Sitango 2011). Therefore, when selecting a suitable sowing date, these climatic conditions have to balance to optimize growth and yield.

Pyrethrum is planted early during the primary rainy season for successful yield development. Later planting will result in poor establishment and low yields in the first year, but subsequent yields will be unaffected. Farmers in the southern highlands used to plant Pyrethrum in April when the rainy season was almost over, regardless of whether the main rains began in December. The late planting time of pyrethrum results in few flower pickings; Instead of picking 32 to 36 flowers a year, you choose 15 to 20 (Wandahwa et al. 1996; Sitango 2011).

This practice has resulted in lower yields and ultimately reduced income for farmers. According to the recommendation, the suitable time for planting the pyrethrum is the beginning of the central rainfall. For example, the appropriate planting months in the Mbeya and Iringa regions are December and January each year (Malimbwi et al. 2013; Baines et al. 2012). However, farmers in the southern highlands plant late. According to (Sitango 2011), the highest pyrethrum yields occurred when sowing was done early at the beginning of the primary rain, while lower yields resulted from sowing late after the rain had ended.

The global increase in average temperatures in recent decades has significantly affected agricultural practices, including pyrethrum germination and growth (Shimira et al., 2021). In Tanzania, farmers have observed the impact of this climate change on pyrethrum productivity, requiring adjustments to conventional farming practices to maintain high yields. One such adaptation is changing sowing dates to better adapt to changing climatic conditions. This study examined the effects of different sowing dates on the growth, yield, and yield components of pyrethrum at three different locations in Tanzania (Agrawala et al., 2003). By analyzing these factors, the study aimed to identify optimal sowing periods that mitigate the adverse effects of global warming, thereby increasing pyrethrum productivity and providing farmers with practical strategies to adapt to changing environmental conditions.

A study conducted by (Fulton et al. 2001a) in Tasmania demonstrated that the choice of planting time profoundly influences yield and its components in pyrethrum. High yields in crops sown in later months are often constrained by smaller plant sizes and a reduced ability to generate many flowering tillers. It has been shown that the number of tillers per plant and the mean dry weight of flowers are yield components that vary significantly with the sowing time. In contrast, the concentration of pyrethrins and the mean number of flowers per tiller show slight variation. According to the Tanzania Agricultural Research Institute, the recommendation for sowing pyrethrum in the southern Highlands of Tanzania Pyrethrum is at the onset of the main rains, specifically at the beginning of December each year.

This study aimed to optimize pyrethrum-planting dates to increase productivity in a changing climate. The study aimed to identify optimal planting times that could mitigate the harmful effects of global warming by systematically assessing the impact of different sowing dates on pyrethrum growth and yield components at three locations in Tanzania. This research aimed to provide actionable insights and recommendations for farmers, enabling them to adapt their planting plans to maintain high productivity despite the challenges of climate change and ensure sustainable pyrethrum cultivation.

2. Materials and Methods

2.1. Study area

The demonstration plots were established and planted at Umalila Highlands in the Mbeya region. Three villages were selected for the planting: Iyunga Mapinduzi, Santilya, and Pashungu. The plots were planted from January to April at monthly intervals.

2.2. Land Preparation and Trial Layout

Land preparation and trial layout were conducted using a Randomized Complete Block Design (RCBD) with three replications, each village representing one replicate. The plot size was 3.6 meters long by 3 meters wide, with six rows per plot planted at a spacing of 0.6 meters by 0.3 meters. Phosphatic fertilizer was applied during planting at 40 kg ha^{-1}, equivalent to 7 grams per hole. Pyrethrum splits were planted from January to April at monthly intervals.

2.3. Planting and Cultivation

The trial was conducted during the rain-fed season. Flower picking began three months after planting, with flowers picked at ten-day intervals.

2.4. Data Collection

The following data were collected:

- Plant survival rates (percentage)
- Dry flower weight (kg ha^{-1})
- Plant height (cm)
- Disease scores
- Plant rosette size (cm)
- Number of plant stalks per plant

Table 1 Outlines the layout of the experiment, with each replication representing a different village.

Replication	Village	Plot size(m)	Rows per plot	Spacing (m x m)	Fertilizer applied (Kg ha-1)	Planting dates
1.	Iyunga Mapinduzi	3.6 x 3	6	0.6 x 0.3	40	16 January, 16 February, 16 March, and 16 April
2.	Santilya	3.6 x 3	6	0.6 x 0.3	40	16 January, 16 February, 16 March, and 16 April
3.	Panshungu	3.6 x 3	6	0.6 x 0.3	40	16 January, 16 February, 16 March, and 16 April

Table 2 Basic soil properties of the 0–20 cm soil layer at the experimental sites

Site	Soil bulk density (g m^{-3})	Organic matter content (g kg^{-1})	Total nitrogen content (g kg^{-1})	Available nitrogen content (mg kg^{-1})	Available phosphorus content (mg kg^{-1})
Iyunga mapinduzi	1.26±0.05	4.88±0.06	0.21±0.01	28.62±0.24	4.61±0.20
Santilya	1.25±0.03	3.18±0.04	0.30±0.01	19.32±0.25	6.62±0.15
Pashungu	1.27±0.01	6.01±0.07	0.25±0.01	25.20±0.36	2.36±0.09

The mean and standard deviation of three replicates are presented.

2.5. Data processing and statistical analysis

Plant and soil measurements were analyzed using the Statistical Package for Social Sciences (SPSS) version 25. Least Significance Difference (LSD) tests at P=0.05 were used to compare means. Graphs were created using the ggplot2 and tidyheatmap packages in the R program.

3. Results

3.1. Effect of planting dates on the pyrethrum yields

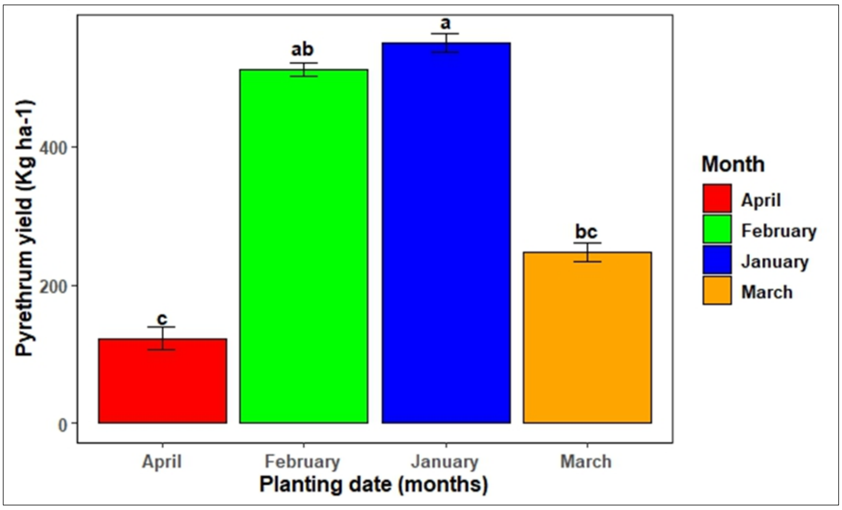

Figure 1 Effects of planting date on the pyrethrum yields (mean weight in kg ha^{-1}). Values are means with standard deviations shown by vertical bars (n=4). Bars with different lowercase letter (s) indicate significant differences at P < 0.05 among the treatments.

The results presented in Figure 1 display the pyrethrum yield (kg ha^{-1}) for different planting dates across four months: January, February, March, and April (control). The yield varies significantly with the planting month. January has the highest yield at approximately 400 kg ha^{-1}, followed closely by February with a slightly lower yield. March shows a moderate yield, while April has the lowest yield at around 100 kg ha^{-1}. Error bars are included to indicate the variability in the yield measurements. Compared with other treatments, pyrethrum planted in January had a higher yield than the different treatments.

3.2. Effect of planting dates on the pyrethrum survival rates

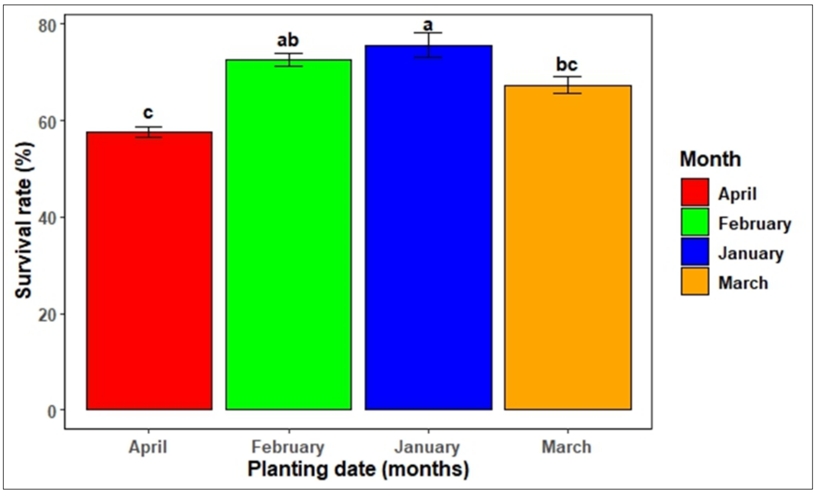

Figure 2 Effects of planting date on the pyrethrum survival rates (%). Values are means with standard deviations shown by vertical bars (n=4). Bars with different lowercase letter (s) indicate significant differences at P < 0.05 among the treatments.

Figure 2 shows that pyrethrum plants' survival rate is highest when planted in January, with a survival rate of around 75%. The survival rate is lower for February, March, and April plantings, at around 72%, 67%, and 57%, respectively.

3.3. Effect of planting dates on the pyrethrum yield components and disease occurrence.

The table presents data on the effect of planting dates (January, February, March, and April) on various yield components and disease occurrence of pyrethrum across three sites: Ivunga Mapinduzi, Santilya, and Pashungu. The components measured include plant height, rosette size, number of stalks, and disease scores. In Ivunga Mapinduzi, January planting yields the tallest plants (60.6 cm) and the highest number of stalks (13), with a rosette size of 7.02 cm and a disease score of 0. April shows the poorest performance in all aspects, with the shortest plants (41.18 cm), smallest rosette size (5.55 cm), fewest stalks (5), and a disease score of 1. Similar trends are observed in Santilya and Pashungu, with January consistently yielding the tallest plants, largest rosette sizes, and most stalks, while April yields the poorest results. Disease scores are generally higher in later months, especially in April.

Table 3 The effect of planting dates on the yield components and disease occurrence in pyrethrum in three sites. The lowercase letter (s) indicate significant differences at $p < 0.05$ among the treatments.

Sites (Villages)	Treatment	Height(cm)	Rosette size	Number of stalks	Disease scores
Iyunga Mapinduzi	January	60.6a	7.02a	13a	0
	February	58.4ab	6.9b	11b	1
	March	51.08b	6.5bc	9c	0
	April (control)	41.18c	5.55c	5d	1
Santilya	January	63.3a	9.5a	15a	0
	February	55.38ab	8.4a	13ab	0
	March	50.5c	6b	8b	1
	April (control)	42.07d	4.5c	3c	1
Pashungu	January	61.1a	12.5a	12a	0
	February	53.07b	11.9ab	10ab	0
	March	48c	10.8b	7b	0
	April (control)	38.5d	6.1c	3c	1

Note: Disease scores 0-5 of the blight light occurrence

The image depicts a correlation matrix for six variables: H, RS, NS, DS, Y, and SR (Figure 3). The correlation matrix shows strong relationships between the variables. Most notably, positive correlations H, RS, NS, Y, and SR are strongly positive correlations with each other. These positive correlations are exceptionally high between H and NS (0.96), NS and Y (0.99), and Y and SR (0.98). Negative correlations: DS is strongly negatively correlated with all other variables, indicating that as DS increases, other variables tend to decrease, and vice versa. The strongest negative correlation is between DS and RS (-0.97).

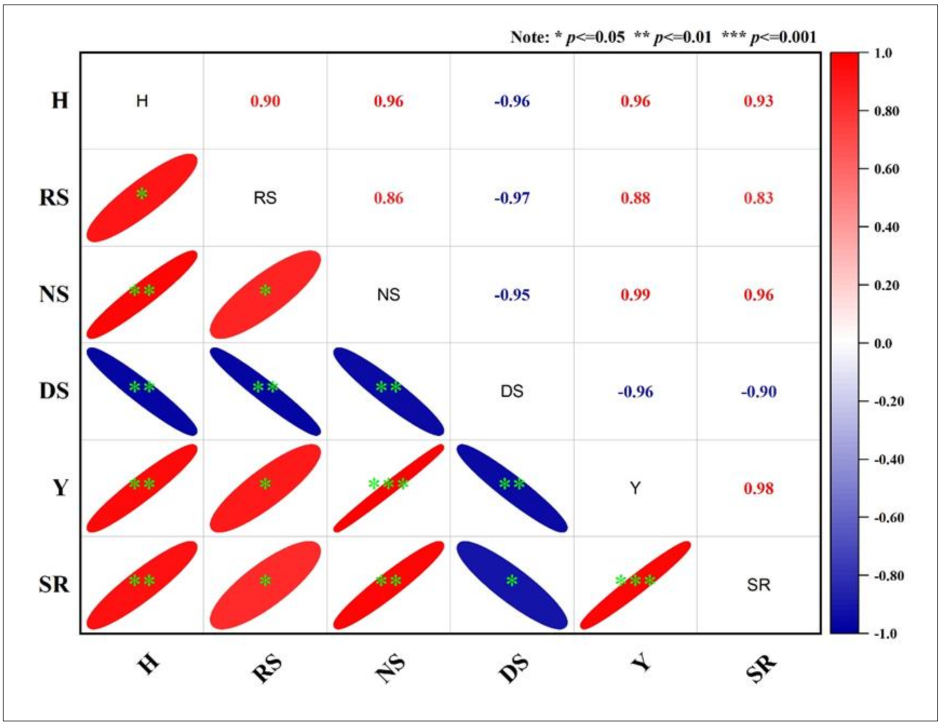

Figure 3 Correlation matrix illustrating the correlation among (H) height (cm), (RS) rosette size, NS (number of stalks), DS (disease score), yield (kg ha^{-1}), and SR (survival rate). Deep red and blue colors show significantly positive and negative relationships, respectively.

4. Discussion

Climate factors like high temperatures (heat stress), water deficit conditions, and photoperiod can influence the flowering period, flower development rate, and, ultimately, the pyrethrin yield of pyrethrum (Suraweera et al. 2020). Properly managing these environmental and agronomic factors is crucial for optimizing pyrethrum flower production and pyrethrin content. It has been observed that sowing/planting date has been identified as a factor affecting flower yields, with late sowings (after mid-November in Tasmania) leading to reduced yields (Suraweera 2016). The highest flower yield was achieved with the early planting dates, as shown in Figure 1. The four planting dates, with April as a control, differed significantly at the 5% level (p=0.05). The flower dry weight was highest in January and February, with a progressive decrease in yield observed in March and April. Pyrethrum planted in January had the highest yield, followed by February, March, and April. Planting dates significantly influenced flower yield, as indicated in Figure 1. The flower weight increased with earlier planting, meaning the earlier the planting date, the higher the yield. The plant survival rate, as shown in Figure 1, also supported yield differences, with January and February showing higher yields than March and April. Our findings align with (Fulton et al. 2001b), who found that the choice of sowing time could profoundly influence yield and its components. Therefore, planting time is vital in determining the pyrethrum flower yield.

For pyrethrum flower yield components and disease occurrence, the results showed that in all three sites, pyrethrum planted in January had the most significant height, rosette size, and number of stalks (Table 3), which were associated with the high yield observed (Figure 1). This is similar to (Fulton et al. 2001b) and (Sitango 2011), who demonstrated that planting date is among the factors affecting dry matter yield and pyrethrin content in pyrethrum in Tasmania. The results also revealed a vital significance in the correlation matrix between the different variables. There was a highly significant difference (p=0.001) between yield and rosette size. All other variables were correlated at p=0.05 (Figure 3). Based on the results and discussion, it is recommended that farmers plant pyrethrum in January. Therefore, farmers in the southern highlands of Tanzania should plan their planting schedules so that pyrethrum is planted in January. This timing maximizes flower yield, as indicated by higher flower dry weight, plant height, rosette size, and number of stems when planted in January. January sowing will also benefit from the higher plant survival rates observed in the study, resulting in a more productive and profitable pyrethrum crop.

5. Conclusion

The study clearly shows that the optimal planting time for pyrethrum in the southern highlands of Tanzania is January. This timing consistently results in the highest flower yield, characterized by superior flower dry weight, plant height, rosette size, and number of stems. The significant yield differences between planting dates, with January outperforming all others, highlight the importance of early planting. The higher plant survival rates associated with January sowing further enhance its benefits. By aligning their planting schedules with this optimal period, farmers can significantly increase their productivity and profitability, ensuring a more successful pyrethrum harvest. Therefore, farmers in this region are strongly recommended to prioritize January for planting pyrethrum to achieve the best possible yield.

Compliance with ethical standards

Acknowledgment

We are grateful to those who contributed their thoughts to make this work comprehensive.

Disclosure of conflict of interest

The authors declare that there is no conflict of interest.

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