Effect of goat manure levels on growth performance of wild watermelon (Citrullus lanatus var. Citroides) cultivated under shade house conditions

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Abstract

The objective of the study was to determine the effect of different goat manure levels on the growth yield and performance of wild watermelon (*Citrullus lanatus* subsp.) cultivated in shade houses. Six treatments comprised different goat manure levels, namely, river sand, Hutton soil, and goat manure T_0-1:3:0 (control), T_1-1:3:1, T_2-1:3:2, T_3-1:3:3, T_4-1:3:4, and T_5-1:3:5. Treatments had a highly significant ($P \leq 0.01$) effect on dry shoot mass (DSM) (g), fruit weight (FW) (g), and fruit diameter (FD) (mm) of wild watermelon plants. The dry root mass (DRM) (g), vine length (VL) (m), and chlorophyll content (CCL) of wild watermelon plants were not significantly affected by the application of goat manure levels. The goat manure levels in T_1-1:31, T_2-1:3:2, T_3-1:3:3, T_4-1:3:4, and T_5-1:3:5 reached the cumulative DSM (6.57, 10.12, 9.17, 11.14, and 8.32). In contrast, all the goat manure levels T1-1:31, T2-1:3:2, T3-1:3:3, T4-1:3:4, and T5-1:3:5 reduced FW (183.56, 72.02, 119.05, 171.87, 9.08 g) compared to the control (1:3:0), achieved 212.14 g, while the highest (183.56, 171.87, and 119.05) were at T1-1:31, T4-1:3:4, and T3-1:3:3, respectively. The smallest FM (72.02 and 9.08 cm) was observed at 1:3:2 and 1:3:5 goat manure levels, respectively. Similarly, all the goat manure levels T1-1:31, T2-1:3:2, T3-1:3:3, T4-1:3:4, and T5-1:3:5 reduced FD (61.03, 40.24, 59.76, 69.66, and 14.40 mm) compared to the control (1:3:0), which was achieved at 78.73 mm. In conclusion, T4-1:3:4 performed well in terms of the DSM. Therefore, goat manure at T4-1:3:4 achieved the best growth performance in wild watermelon.

Introduction

The wild watermelon (*Citrullus lanatus* subsp.) is a vine plant that evolved in Southern Africa. It is an herbaceous species that belongs to the Cucurbitaceae family (Renner and Schaefer 2016). More than 700 species of herbaceous crops and roughly 90 genera—regarded as significant crops—are included in the Cucurbitaceae family. It is considered economically important and is grown worldwide in warm climates for its fruit and leaves, which are used as vegetables after being cooked. Mature fruits can stay whole and juicy for over a year after being removed from their parent plant native throughout Africa and southwest Asia, wild watermelon (Ncebo 2010). Since pre-colonial times, wild watermelons have been developed in South Africa with sorghum and maize (Fox and Norwood Young 1982) to boost food production in some areas, such as KwaZulu-Natal.

Given that wild watermelon is native to Southern Africa's arid regions, it may be able to withstand drought. However, studies on its resistance to drought are difficult to find in the literature. In addition to drought, it grows wild in grasslands and shrublands. It also frequently grows under cultivation in Mpumalanga, North West, Limpopo, KwaZulu-Natal, Free State, the Western Cape, and the Eastern Cape (DAFF 2013). It is frequently found on sandy soils in the Kgalagadi region of the Northern Cape. The availability of wild watermelon for food during the hunting season determined the historical movement of people from one location to another.

Wild watermelons can grow to full maturity in almost any soil. However, warm, dry weather is needed for maximal production, and they are primarily frost-sensitive (McDonald and Copeland 1997). An excellent growing soil mixture is one of the most critical factors in any vegetable crop's thriving farming and production, including wild watermelon (Abad et al. 2002). One study by Huntley et al. (1997) claims that organic fertilizers—made from animal products—are among the most essential and traditional fertilizers. The primary sources of animal products that contain the macronutrients N, P, and K on a dry mass basis are beef cattle, hogs, horses, sheep, goats, and poultry. These sources constitute approximately 2.0%, 0.5%, and 1.5% of the corresponding variables. Reduced soil fertility and shortages in minerals and nutrients that impact regular plants have generally been linked to reduced crop production (Nkweke et al. 2013). Native vegetable plants with leaves, such as wild watermelons, also need nutrition to thrive. For their development, the most important chemical feature is adequate soil fertility. Low nutrient levels, acidifying African soil, and nitrogen imbalances all impact soil (AGRA 2019). Although synthetic fertilisers significantly impact crop productivity and production, their constant use has a detrimental effect on the health of the soil and future crop potential. Thus, most productive soil becomes unproductive under agricultural methods, and the issue worsens. Degradation of the soil is another effect of fertilizer accumulation, an ongoing process. Fertilizer residues damage vital beneficial pathogens that keep soil fertility high, which leads to soil degradation. As a result, agricultural yields are reduced because soil fertility is degrading or declining (Ojo et al. 2014), and environmental sensitivity to agricultural husbandry is increased due to poor management (Mosier et al. 2021). Furthermore, smallholder farmers in rural areas face high costs associated with synthetic fertilizers (Antony et al. 2013).

The sole way to address ongoing issues may be to use organic manure, such as goat dung, as fertilizer. Manure is a new technique that doesn't hurt the environment and can allow nutrient-rich organic soil fertilizer development. According to Washaya and Washaya (2023), using organic waste as fertilizer is an alternative to disposing of organic agricultural waste, decreasing pollution. In Tanzania, goat manure performed better than cattle manure (Maerere et al. 2009), and it influences plant development as well as the chemical composition of the soil. According to Ndung'u et al. (2021), goat manure is reported to contain enough nutrients to meet the needs of maize plants for optimal growth. It is still shameful that manure is not usually put on agricultural land in Sub-Saharan African (SSA) nations (Washaya and Washaya 2023). There is no literature on increasing wild watermelon yields, even though numerous studies on the use of goat manure as soil fertility have been conducted (Ansah et al. 2019; Batubara et al. 2021; Mbatha et al. 2021; Köninger et al. 2021), but very few have used. Thus, the study aimed to determine the effect of different goat manure levels on the growth yield and performance of wild watermelon (*Citrullus lanatus* subsp.) cultivated in shade houses.

Materials and methods

Description of the study area

The study was conducted at the Aquaculture Research Unit (ARU), University of Limpopo, South Africa (23°53'10"S, 29°44'15"E), in summer (October-January) 2023/2024. The site had Hutton sandy loam (65% sand, 30% clay, 5% silt), with organic C at 1.6%, electrical conductivity of 0.148 dS/m, and pH (H_2O) 6.5. Minimum/maximum ambient temperatures averaged 13/38°C in a shade house. The length and width of the shade house were 30 m and 15 m, respectively, with the roof covered with a white and plastic net that allowed 80% photosynthetically active radiation.

Treatment and design of experiments

Hutton soil, river sand and goat manure were the six treatments, which were distributed as follows: T_0-1:3:0 (control), T_1-1:3:1, T_2-1:3:2, T_3-1:3:3, T_4-1:3:4, and T_5-1:3:5. A randomised complete block design (RCBD) was used to schedule the treatment, with fourteen replications (n = 84). Goat manure was collected from the University of Limpopo, Syferkuil Experimental Farm in the goat kraal, and river sand was collected from a stream close to the University of Limpopo Experimental farm, which is located 9 km northwest of the university's main campus (Fig. 1). Hutton soil was obtained by digging at the Green Biotechnologies Research Center of Excellence (GBRCE) open field at the University of Limpopo.

Procedures

The mature fruit of wild watermelon plants was collected from a cultivated field in Khureng Village, Zebediela, Lepelle-Nkumpi Municipality (located at 24°33'53" S, 29°23'4" E) in the South African province of Limpopo (Fig. 2). The fruit was then chopped into pieces, and its seeds were extracted. Before being sown in 200-hole seedling trays filled with Hygromix-T (Hygrotech, Pretoria) growing medium, seeds were shade-dried for 72 hours. The seeds then germinated in a shade house with an average temperature of 38ºC. One week after the seedlings had been hardened off outside the shade house by intermittently withdrawing irrigation. Before planting, a test was done on the viability of the seeds. Uniform seedlings at the five-leaf stage were transplanted into 18-cm-diameter plastic pots, which were filled with 2 430 ml of steam-pasteurized (300°C for 1 hour) Hutton soil, sand, and non-pasteurised goat manure at varying ratios. On shade house benches, potted seedlings were arranged with a 0.40 m × 0.30 m inter-row and intra-row spacing (83 333.33 plants ha^{-1}). Five days after transplanting, 2 g 2:1:2 (43) Multifeed (Nulandis, Witfield, South Africa) was applied through irrigation into each pot, providing 0.70 mg N, 0.64 mg K and 0.64 mg P, 1.8 mg, 1.5 mg Fe, 0.15 mg Cu, 0.7 mg Zn, 2 mg B, 6 mg Mn, and 0.14 mg Mo/ml of tap water. In pots containing seedlings, seven iTuin Metre moisture probes (Institute of Opto-Electronic Technology, Beijing) were placed individually. Every day, plants were scouted for pests, and when insect populations grew to more than ten per plant, Kemprin 200 EC (the active ingredient cypermethrin) was sprayed on the plants per package directions. When readings from 50% of the moisture meters were slightly below two units, plants were irrigated with 300 ml of tap water.

Data collection

Eighty-four (84) days after the treatments were started, plant growth parameters were collected and recorded. A one-meter ruler was used to measure the plant's vine length (PVL) from the base of the main stem to the highest. The Chlorophyll meter (CCM200 Plus, Opti-36 Sciences, USA) was used to measure the leaf chlorophyll content (CCL), and the Vernier calliper (standard, Mitutoyo, India) was used to determine the fruit diameter (FD). Fresh fruit weight (FW) was measured using a digital balance (Model NO: NBT-A3000, China). After that, the gathered shoots and roots were oven-dried for 72 hours at 60°C, and the dry shoot mass (DSM) and dry root mass (DRM) were measured.

Data analysis

The normality of the data distribution was performed using the Shapiro-Wilk test (Ghasemi and Zahediasl 2012; Shapiro and Wilk 1965). Data were subjected to analysis of variance (ANOVA) through the SAS software (SAS Institute 2010). The degree of freedom and mean sum of squares (MSS) were partitioned to provide the total treatment variation (TTV). Mean separation was achieved using the Waller-Duncan multiple range test at the probability level of 5%. Bar charts were also used to show the differences. Unless otherwise stated, only treatments' mean significance at the probability level of 5% were discussed.

Results

Treatments had a highly significant ($P \leq 0.01$) effect on dry shoot mass (DSM) (g), fruit weight (FW) (g), and fruit diameter (FD) (mm) of wild watermelon plants (Table 1). The dry root mass (DRM) (g), vine length (VL) (m), and chlorophyll content (CCL) of wild watermelon plants were not significantly affected by the application of goat manure levels (Table 1). All goat manure levels reached the highest DSM as compared to the control (Fig. 3(A)). The goat manure levels in T_1-1:31, T_2-1:3:2, T_3-1:3:3, T_4-1:3:4, and T_5-1:3:5 reached the cumulative DSM (6.57, 10.12, 9.17, 11.14, and 8.32) (Table 2). In contrast, all the goat manure levels T1-1:31, T2-1:3:2, T3-1:3:3, T4-1:3:4 and T5-1:3:5 reduced FM (183.56, 72.02, 119.05, 171.87, 9.08 g) compared to the control (1:3:0), achieved 212.14 g), while the highest (183.56, 171.87 and 119.05) at T1-1:31, T4-1:3:4 and T3-1:3:3 respectively (Table 2 and Fig. 3(B). The smallest FM (72.02 and 9.08 cm) was observed at 1:3:2 and 1:3:5 goat manure levels, respectively (Table 2 and Fig. 3(B)). Similarly, all the goat manure levels T1-1:31, T2-1:3:2, T3-1:3:3, T4-1:3:4 and T5-1:3:5 reduced FD (61.03, 40.24, 59.76, 69.66 and 14.40 mm) compared to the control (1:3:0), which was achieved 78.73 mm (Table 2 and Fig. 3(C)). The highest (61.03, 40.24, 59.76 and 69.66) FD at T1-1:31, T2-1:3:2, T3-59.76 and T4-1:3:4 respectively (Table 2 and Fig. 3(C)).

Discussion

The observations in the current study indicated that all goat manure levels significantly affected wild watermelon's DSM, FW, and FD. Similarly, observation was shown in another study elsewhere by Handajaningsih et al. (2018), where the application of goat manure had a significant effect on leafy area (LA), FW, fruit flesh thickness (FFT) and FD. The highly significant effects in this study could be attributed to the timely application of goat manure. The timing of the proper fertiliser application affects flower weight and the diameter size of cabbage production (Pattinasarany 2001). The observation from one of the studies elsewhere indicated that applying organic materials before 30 days of planting achieved better results in the yield of sweet potatoes (Susanto et al. 2014). Cho et al. (2017) also indicated that organic manures are a good source of nutrient density; however, they require mineralisation before being available for plant uptake. The results in this study could be an effect of goat manure at different rates, which provides nutrients of organic manure applied, which was based on the observation by Emeghara et al. (2020).

There is no significant difference in DRM, VL, and CCL found on wild watermelon leaves that were applied to different levels of goat manure. This was supported by the work of Budiastuti et al. (2012), where applying a mixture of goat, cow manure, and NPK solution was not significantly different on melon leaves. The observation in the current study could be attributed to various factors that could influence the significant differences in wild watermelon plants. The non-significant differences in DRM, VL, and CCL in this study could be attributed to a slow release of nutrients in denser goat manure, or the decay of goat manure could take longer, which makes nutrient composition unavailable during a specific period. This occurrence was in line with the observation that organic concrete in the compost was challenging to decompose (Sutanto 2002). The non-significant difference, particularly on CCL in the current study, could probably be encouraged by significantly lower nitrogen levels due to ammonium (NH_3) volatilization, which leads to an imbalance of nutrients (Lim et al. 2023), likely may be induced by high temperatures in the shade house. In addition, Jones et al. (2013) also indicated that significant NH_3Most studies conducted by Ansah et al. (2019), Prieto et al. (2019), and Zhu et al. (2020) indicated that goat manure contains a low C:N ratio below the critical level of 20. This suggested that after ammonia volatilization, there was a shortage of C:N ratio in wild watermelon plants. Wild watermelon is considered a heavy feeder of N and, therefore, requires more N to encourage the production of proteins, nucleic acids (DNA and RNA), and chlorophyll synthesis.

The result from this study showed that DSM (6.57, 10.12, 9.17, 11.14, and 8.32 g) was accumulated in T_1-1:31, T_2-1:3:2, T_3-1:3:3, T4-1:3:4, and T_5-1:3:5 goat manure levels compared to control 6.54 g. The highest DSM reported in the current study was achieved in T_4-11.14 g, followed by T_2-10.12 g, T3-917 g, T5-8.32 g, and T1-6.57 g in goat manure. The high DSM growth in T4-11.14 g could be because goat manure as T_4 boosts the organic manure content to acceptable levels due to organic manure improving plant root rizoster condition (Mbatha et al. 2021), thus enhancing the accumulation of nutrients from the soil. Batubara et al. (2021) indicated that the soil's organic matter content, which is < 2%, is not optimal for crop production. The nutrient composition of manure, mainly the C:N ratio, is the most critical for the production of crops and plants. Gross and Glaser (2021) specified that the accumulation of manure in agricultural soil increased soil organic carbon stocks by 35.4%. In general, plant development is an accumulation of DSM over time (Mudalahothe et al. 2022), whereas plant DSM is the translocation of photosynthesis to all vegetable organs. Hence, a plant's growth rate is determined by the rate of the leaf that captures the solar radiation with the optimum photosynthesis rate (Paulus 2010). To this end, T_4 goat manure is recommended that farmers use it to increase the total availability of N, P, organic matter content, soil pH, exchangeable cations (K, Ca, and Mg), and cation exchange capacity (CEC) in the soil solution (Uwah and Eyo 2014).

The current study showed that the application of different goat manure levels significantly reduced fresh fruit weight as compared to the control. However, the highest fruit weight was achieved in T_1-183.56 g, followed by T_4-171.87 g, T_3-119.05 g and T_2-72.02 g in the respective variables. The lowest fruit weight was achieved in T_5-9.08 g. This recommended that the control, without application of goat manure, increase the fruit weight to 212.14g and the diameter of fruit thickness to 78.73 mm. The observation from this study contradicts the result by Handajaningsih et al. (2018), who observed a positive linear response to the application time of goat manure. It was noticed that the application of goat manure was slightly subordinate in terms of its effect on fruit weight development in wild watermelons. The reduction of FW in this study could be attributed to the slow release of goat manure. It has been reported that there is a slow release and accumulation of N, P, and K in cactus aboveground biomass when using goat manure (Saraiva et al. 2021). Goat manure has a slower release rate than cow manure, suggesting that it will provide nutrients to plants over a longer period of time. Zhu et al. (2020) specified that manure from different animal species has different chemical compositions and might result in different decomposition rates. Good quality melon fruit is categorized by big fruit size and thick mesocarp size. Fruit expansion is naturally characterized as proceeding through four stages: fruit set that comprises fertilization and ovary development; fruit development, which is achieved mostly by cell enlargement; fruit development due generally to cell division that includes seed formation and early embryo development and the final maturation and ripening (Okello et al. 2015).

Conclusion

The results of this study suggest that to maximize DSM growth performance in wild watermelon, goat manure at T_4 may be desirable. The organic matter content, optimal availability of N and P, cation exchange capacity, and soil pH in the soil solution would all increase if T_4 of goat manure were used. To achieve the best DSM production, therefore, it may be recommended that goat manure be added to the agricultural soil at T_4 for wild watermelon. This may lead to crosswise fertilization strategies that are more likely to lead to nutrient balances with large nutrient surpluses into soil profile. Goat manure is also less expensive and enhances the structure of the soil.

Declarations

Author Contributions Statement Tseke PE was in charge of project-experiment administration, writing original draft of the report, and interpreting the findings. Mphosi MS was in charge of the data analysis and results interpretation. Review and editing draft of the manuscript. Maila MY was in charge of setting up the experiment, and review and editing draft of the manuscript.

Data Availability

Upon request from the corresponding author, data used to support the findings of this study will be made available for a reason.

Declaration of Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Tables

Table 1. Responses of dry root mass (DRM) (g) and dry shoot mass (DSM) (g), fruit weight (FW) (g), fruit diameter (FD) (mm), vine length (VL) (m), and leaf chlorophyll content (CLC) of wild watermelon under different goat manure levels

Treatment	DRM	DSM	FW	FD	VL	CLC
1:3:0	$0.90^{a} \pm 0.23$	$6.54^{c} \pm 1.0$	$212.14^{a} \pm 33.8$	$78.73^{a} \pm 9.3$	$0.92^{ab} \pm 8.1$	$26.03^{b} \pm 2.3$
1:3:1	$0.61^{a} \pm 0.11$	$6.57^{c} \pm 0.9$	$183.56^{ab} \pm 40.8$	$61.03^{a} \pm 11.1$	$1.00^{ab} \pm 8.8$	$33.12^{a} \pm 3.4$
1:3:2	$0.66^{a} \pm 0.07$	$10.12^{ab} \pm 1.0$	$72.02^{cd} \pm 22.1$	$40.24^{b} \pm 9.5$	$1.05^{ab} \pm 11.2$	$27.46^{ab} \pm 1.9$
1:3:3	$0.77^{a} \pm 0.13$	$9.17^{abc} \pm 0.9$	$119.05^{bc} \pm 26.1$	$59.76^{ab} \pm 9.2$	$1.06^{ab} \pm 10.1$	$24.03^{b} \pm 1.5$
1:3:4	$0.83^{a} \pm 0.08$	$11.14^{a} \pm 1.1$	$171.87^{ab} \pm 32.6$	$69.66^{a} \pm 8.8$	$1.09^{a} \pm 7.4$	$27.45^{ab} \pm 2.4$
1:3:5	$0.73^{a} \pm 0.23$	$8.32^{bc} \pm 0.9$	$9.08^{d} \pm 4.1$	$14.40^{c} \pm 5.1$	$0.86^{b} \pm 8.1$	$29.04^{ab} \pm 2.5$
P-value	NS	0.01	0.01	0.01	NS	NS

Means ± standard deviation within a column followed by the same letter are not significantly different at the 5% level of significant according to the Waller-Duncan multiple range test.
^{NS} = Not significant at $P \leq 0.05$ according to the Waller-Duncan multiple range test.
Highly significant at $P \leq 0.01$ according to the Waller-Duncan multiple range test.

Figures

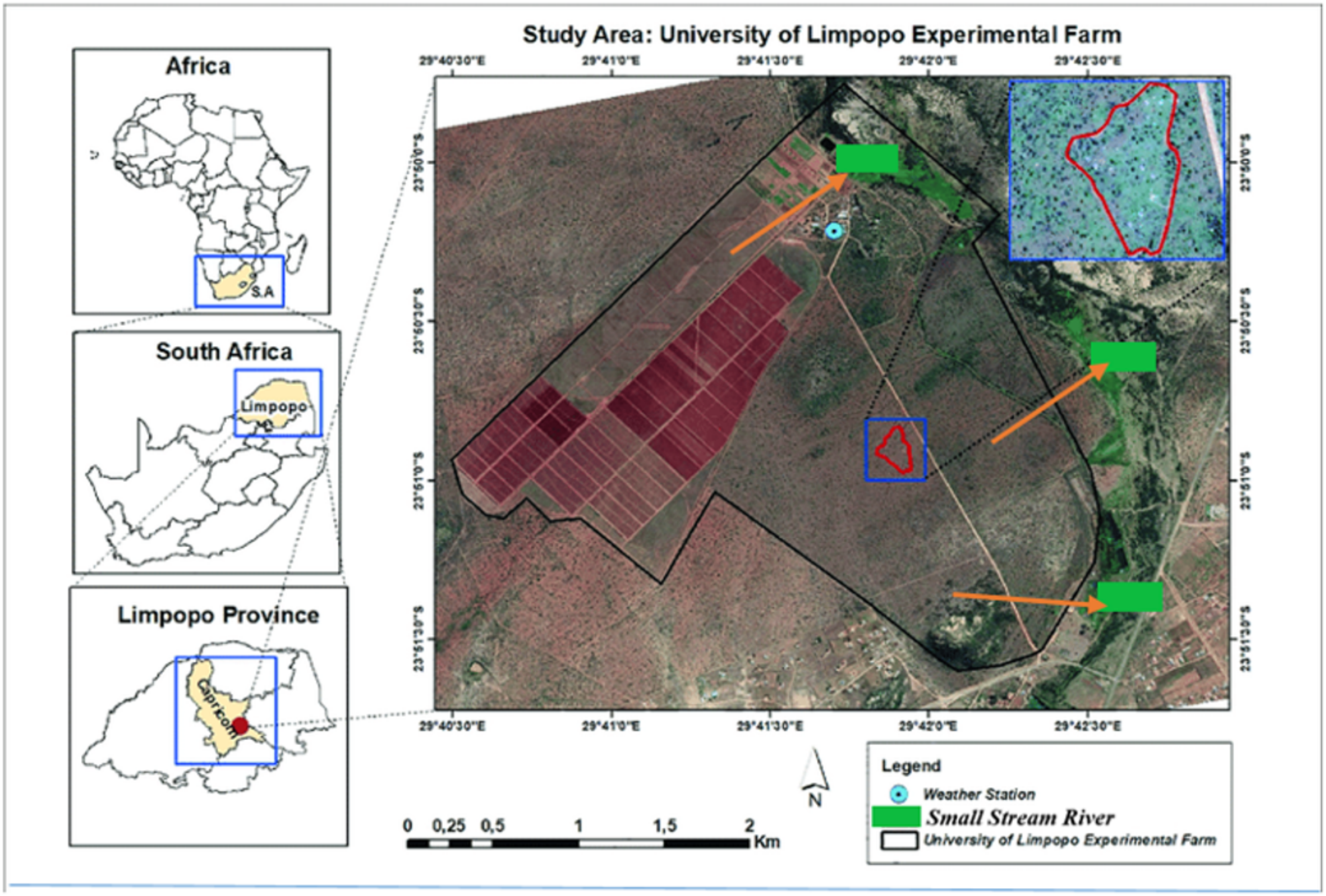

Figure 1

Location of the stream close to the University of Limpopo Experimental Farm.

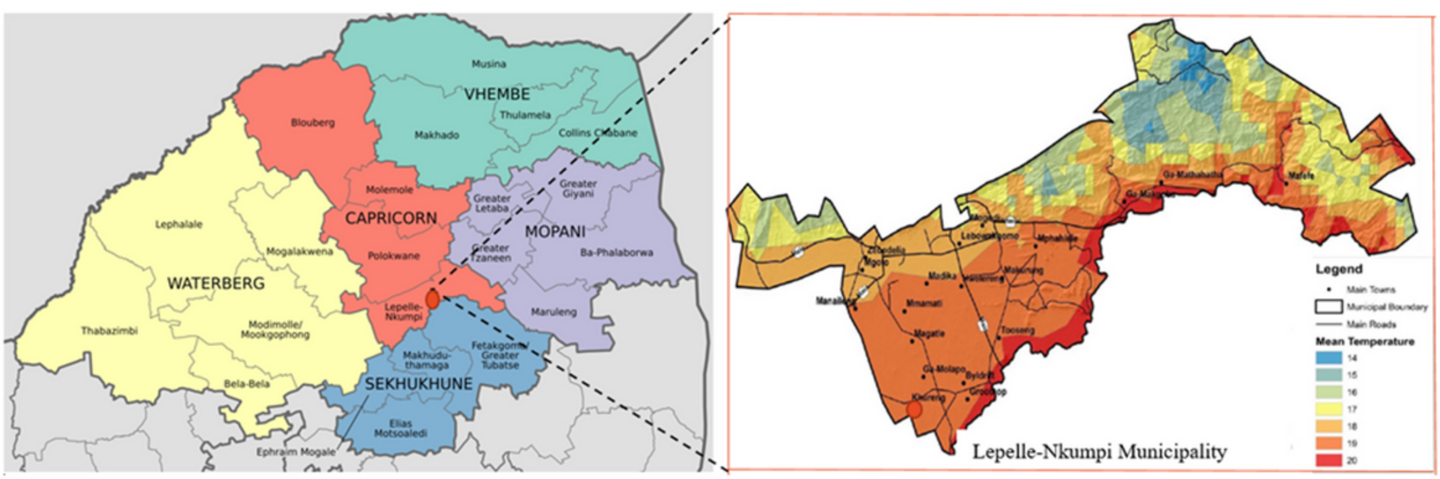

Figure 2

Location of Khureng Village, Zebediala, Lepelle-Nkumpi Municipality in the South Africa, Limpopo Province.

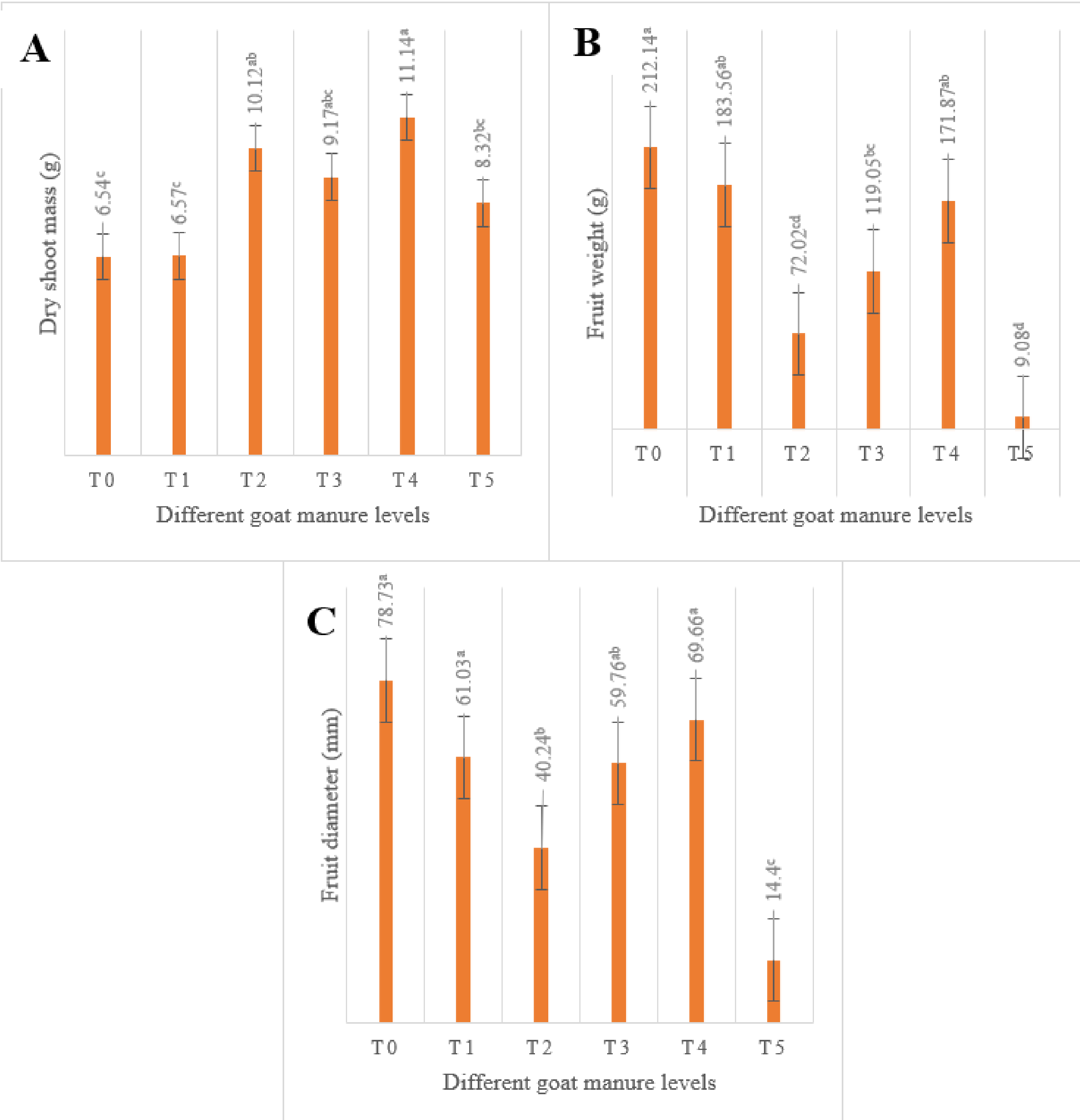

Figure 3

Responses of **A**-dry shoot mas (DSM), **B**-fruit weight (FW), and **C**-fruit diameter (FD) of wild watermelon to different levels of goat manure under shade house conditions