The effects of day temperatures and soil moisture levels on the germination parameters of Cleome gynandra (L.)

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Abstract

Cleome gynandra (L.), an orphan crop is generally well adapted to tropical and sub-tropical conditions. It is drought tolerant and resilient annual vegetable crop capable of growing well in diverse conditions. However, there exists gaps in known information about the crop on its germination biology which is important if the crop is to be adopted for commercial production. Therefore, the objective of this study was to determine the effects of soil moisture and temperatures on the germination parameters of *C. gynandra*. The experiment was a 4*3 factorial experiment laid down as a randomised complete block design replicated three times and done twice over time. Data collected included germination percentage, mean daily germination and germination speed. The data was analysed using the Genstat version 18. The results showed that a significantly ($P < 0.05$) higher germination percentage was obtained on day 14 at 100% soil moisture content. Germination percentage significantly ($P < 0.05$) increased from 25% soil moisture content to a maximum of 60% at 100% moisture content on day 14 with a correlation of R^2 = 0.87 to 0.96 which shows the closeness of the relationship at day 7 to day 14. In terms of the temperature requirements for germination, 30^{o}C gave the highest germination speed ($P < 0.05$). The trend was the same for all germination parameters that included mean germination time, mean daily germination, germination percentage and speed of germination. It can therefore be concluded that 100% moisture content and 30^{o}C gave the most suitable conditions for *C. gynandra* germination. This study implies that the same conditions can be used during nursery establishment.

Key Points

• Identify the importance of Cleome gynandra as an important climate resilient vegetable

• Assessing the factors affecting the germination of Cleome gynandra seeds with a view on commercialisation

• Results can guide nursery establishment for the crop in the future

Introduction

Cleome gynandra is highly valued for its edible leaves and medicinal properties and is native to sub-Saharan Africa and Southeast Asia, where it is recognized by various local names [1, 2, 3]. It exhibits remarkable adaptability, thriving in disturbed areas, along roadsides, and in cultivated fields. This versatility contributes to its classification as a weed in certain environments. In sub-Saharan Africa, it is found in several countries, including Botswana, Kenya, Malawi, Namibia, South Africa, Tanzania, Eswatini, Mozambique, Uganda, Zambia, and Zimbabwe [4, 5, 6, 7]. The same countries are located in the climate 'hotspot' in southern Africa hence the possibility of the crop to be exploited for food and nutrition security. *Cleome gynandra* is gaining recognition as a promising leafy vegetable, particularly suited for tropical and subtropical climates where it thrives naturally. Its potential for development as a significant crop is especially pertinent in the context of food security for rural communities in Africa [8]. The plant serves multiple roles, including providing food, medicinal applications, animal feed, and even functioning as a plant protectant [9].

A search of Genesys, the Global Information Portal for Plant Genetic Resources, which only covers around a third of crop accessions conserved *ex situ* in gene banks worldwide, found at total of 331 *C. gynandra* accessions, the vast majority stored at the AVRDC World Vegetable Center, with most of the rest at the Millennium Seed Bank in the UK. They are mostly African in origin, but a large number originate from South East Asian countries. There are also accessions listed under the synonyms *Gynandropsis gynandra* and *G. pentaphylla*. In addition, collections are maintained across Africa in Botswana, Kenya, Namibia, Tanzania, Zambia, and Zimbabwe.

According to Mashamaite et al.,[10] the crop is a drought tolerant and resilient annual vegetable crop capable of growing well in a wide range of climatic and edaphic conditions. Mabhaudhi et al., [11] further asserts that the crop can thrive with little human support and this illustrates its potential as a future crop in the changed climate. The crop can thrive in fragile and marginal conditions especially in degraded lands [12]. The crop is a rich source of nutrients comprising of proteins, vitamins (A and C) and minerals calcium, iron, sodium, iodine, zinc and they are found in quantities greater than conventional vegetables [13, 14]. Actually, the effective utilisation of wild vegetables such as *C. gynandra* has been proposed as an alternative solution to address the problem of dietary deficiencies especially micronutrient deficiencies which come from the overdependence on the conventional vegetables.

Despite the potential benefits of *C. gynandra*, its development as a crop has been impeded by low research, low yields, poor seed quality [10] and the limited understanding of its germination biology which can optimise its production in the nursery. *C. gynandra* enter physiological dormancy for 4–5 months after harvest and only germinate from six months after harvest [15]. Kwarteng et al.,[16] asserts that the germination process is integral to its domestication as reduced germination leads to reduced crop establishment and low yields. According to Raboteaux and Anderson [17], the seeds of *C. gynandra* are negatively photoblastic and exposure to light for longer periods of 12 hours reduces germination due to photo-inhibition. Research by Ochuodo and Modi [18] investigated the effect of temperature, light and pre-germination treatments on *C. gynandra* seed and the results showed that alternating temperatures of 20–30 ^{O}C under dark conditions produced the highest germination. Actually, Ochuodho and Modi [18] found that the highest germination percentages 60 and 80% occur for a 2-year-old and 1 year-old seedlots respectively of untreated seed was achieved under temperatures of 20–30^{O}C in the dark or constant 30^{O}C in the dark were used.

Germination is a critical stage in the life cycle of plants and controls the population dynamics. The germination and early establishment of *Cleome gynandra* are crucial for the successful cultivation of this valuable leafy vegetable, particularly in regions like Southern Africa, where it is an important food source. However, various environmental factors, such as temperature, and moisture, significantly influence these processes. This lack of knowledge poses a challenge for farmers seeking to optimize production conditions, leading to inconsistent crop yields and potentially affecting food security. Therefore, investigating the effects of temperature, and moisture on the germination parameters of *C. gynandra* seeds provides critical insights that can inform cultivation practices and enhance agricultural productivity. Therefore, the objectives of this study were to determine the influence of temperature and moisture levels on the germination and early growth of *C. gynandra* seedlings.

Methodology

Site description

This research study was conducted at Bindura University of Science Education Campus located 1 Km south of Bindura town along Trojan Road. It is located in natural region 2a according to the Zimbabwean classification system. The region receives 700–1050mm per year received in summer. The altitude is 1400m.

Source of planting material

The seeds were obtained from plants maintained at a garden at Astra campus of the Bindura University of Science Education. The coordinates are $17^0$18'58.7"S 31^o19'25.1"E. This is a commonly consumed wild vegetable in Southern Africa.

Experimental Design and treatments

The experiment was set up as a 4*3 factorial experiment laid down as a randomized complete block design and replicated three times. The experiment was also repeated twice over time. The first factor was soil moisture content at four levels: 25%, 50%, 75% and 100% of field capacity represented by M_1, M_2, M_3 and M_4 respectively. The second factor was temperature at three levels: 20^oC, 30^oC and 35^oC represented by T_1, T_2 and T_3 respectively. The treatments are as shown in Table 1.

Table 1
Treatment combinations and descriptions

Treatment combination	Description
T_1M_1	Germination at 20 ^oc and 25% soil moisture content
T_1M_2	Germination at 20 ^oC and 50% soil moisture content
T_1M_3	Germination at 20 ^oC and 75% soil moisture content
T_1M_4	Germination at 20 ^oC and 100% soil moisture content
T_2M_1	Germination at 30 ^oC and 25% soil moisture content
T_2M_2	Germination at 30 ^oC and 50% soil moisture content
T_2M_3	Germination at 30 ^oC and 75% soil moisture content
T_2M_4	Germination at 30 ^oC and 100% soil moisture content
T_3M_1	Germination at 35 ^oC and 25% soil moisture content
T_3M_2	Germination at 35 ^oC and 50% soil moisture content
T_3M_3	Germination at 35 ^oC and 75% soil moisture content
T_3M_4	Germination at 35 ^oC and 100% soil moisture content

Agronomic management

The soil used in the experiment was dried for 24 hours to get rid of the water and was used to fill the pots. Each pot was filled with 1200g of soil. Each pot had three drainage holes at the bottom to facilitate free drainage. The pH of the soil was 4.8 which is acidic and representative of soils in most small-scale rural farms of Zimbabwe where the crop is cultivated.

Determination of field capacity

Field capacity is the amount of soil moisture or water content after excess water has drained away and the rate of downward movement has materially decreased and takes place in 2–3 days after watering or rain. For determination of percentage field capacity in this experiment it was calculated by the following formulae:

FC = Vw/Vs *100

Where FC is the field capacity; Vw is the volume of water held in the soil after drainage in m^3 and Vs is the total volume of soil (m^3).

The various percentages were determined from the 100% moisture content calculated using the above method. The seeds were watered after every five days. There were four different treatments of moisture, thus 25%, 50%, 75% and 100%, each replicated thrice under different environmental conditions. A watering can with a fine rose was used to irrigate the pots after the amount of irrigation water was measured in a measuring cylinder.

Planting

The *C. gynandra* seeds were counted and packed into sachets. Each sachet contained 30 seeds. The *C. gynandra* seeds were directly sown at 30 seeds per pot. They were spread evenly within each pot. The seeds were provided with irrigation of different amounts of water.

Data Collection

Data collected included germination percentage, germination speed, mean germination time, mean daily germination, peak value and chlorophyll. Analysis of variance was done using Genstat and where there were significant differences, the means were separated using the least significant differences at 0.05 probability level.

Speed of germination

Speed of germination was calculated by the following formula:

Speed of germination = $n1/d1 + n2/d2 + n3/d3+$----------

Where, n = number of germinated seeds, d = number of days.

Mean germination Time (MGT)

$MGT = \Sigma n.D / \Sigma n$

where n = number of seeds newly germinated at time D;

D = days from the beginning of the germination test,

Σn = final germination.

Mean daily germination (MDG)

Mean daily germination can be calculated by the following formula:

MDG = Total number of germinated seeds/ Total number of days

Results and Discussion

Seed germination is affected by the ecological conditions prevailing in the habitat, it depends on several environmental conditions such as light, temperature, moisture and germination media. For *C. gynandra* seeds it is known that they are negatively photoblastic and meaningful germinations will be realized after six months from harvest when dormancy will be broken.

The results showed that maximum germination of *C. gynandra* was achieved at day 14 at 100% moisture content reaching a maximum of about 55% germination percentage (Fig. 1). Germination percentage increased with increase in soil moisture content across all the measured period with correlation coefficients of about 0.9 (R^2 = 0.9) (Fig. 1).

The reason for the trend could have been the fact that seed germination is extremely sensitive to drought stress and that sufficient water is necessary for seeds to break dormancy and develop from heterotrophic immature embryos to autotrophic seedlings [18, 20]. According to Bita and Gerats [21] and Goldack et al.,[22] abiotic conditions such as drought inhibit germination. Actually, according to Sousaraei et al., [23] and Soltani et al., [24], the water cue is able to control the timing of germination 0f all seeds through the requirement for base water potential for germination. This implies that for successful *C. gynandra* cultivation there is need to keep moisture content high nearing 100% to get the maximum seed germination.

The results also showed a significant interaction effects ($P < 0.05$) of soil moisture and temperature on the germination percentage of *C. gynandra* seeds. The results showed that at 100% moisture, a temperature of 30°C resulted in the greatest germination while the least was at 25% moisture (Fig. 2). It is critical to understand that germination occurs when the temperature requirement for germination overlaps with habitat temperature [25, 26].

Speed of germination

The speed of germination was significantly higher ($P < 0.05$) at 100% moisture content across all the measured period from seven days, 10 and 14 days after planting (Fig. 3) with correlation coefficients of R^2 values of 0.94, 0.97 and 0.96 respectively.

A significant interaction ($P < 0.05$) of moisture content and temperature on the speed of germination revealed that a temperature of 30°C gave significantly higher ($P < 0.05$) germination speed at 75 and 100% moisture content compared to 25 and 35°C while there were no significant differences and 25 and 50°C (Fig. 4).

Germination speed is a measure of the rate of germination in terms of the total number of seeds that germinate in a time interval. Therefore, water supply had a significant effect ($P < 0.05$) on the number of

C. gynandra seeds that germinated per unit time. This corroborates with Dewley and Black, [27] and Ozden et al.,[28] that water hydrates the crucial processes of the protoplasm, supplies dissolved oxygen, softens the seed's outer layers and improves seed permeability. Therefore, for maximum germination speed, the soil moisture is supposed to be kept at 100% of field capacity.

Mean daily germination

The mean daily germination was significantly ($P < 0.05$) affected by soil moisture content and it increased as soil moisture increased (Fig. 5) with a correlation coefficient of $R^2 = 0.867$ signifying a closer relationship between the two.

The results also showed a significant ($P < 0.05$) interaction between temperature and soil moisture on mean daily germination (Fig. 6).

A temperature of 30^{o}C gave significantly ($P < 0.05$) higher mean daily germination at 50, 75 and 100% moisture content. No differences were observed at 25^{o}C. According to Soltani et al.,[24] mean daily germination is the measure of the time it takes for the seed to germinate focussing on the day on which most seeds germinated. Moisture remains key to all germination parameters. Water stress decreases mean daily germination [29, 30]. Water is vital for seed enzyme activation, breakdown, translocation and endospermic stored materials [31]. The greater the degree of moisture stress, the greater the decline in the levels of these parameters. The results also show how temperature is critical in regulating germination duration [32, 33].

Conclusion

Therefore, it can be concluded from this study that a temperature of 30o^{o}C and a moisture level of 100% improved all the measured germination parameters which included germination percentage, speed of germination and mean daily germination. The parameters are of paramount importance when establishing a nursery for commercial crop production. In addition to the already available knowledge on seed germination which included that seed of *C. gynandra* are negatively photoblastic and that dormancy ends at six months after harvest, it can therefore be ascertained that it is feasible to produce the seedlings under nursery as long as appropriate conditions are provided in the nursery to maximise germination. This may enable farmers who may want to go into commercial production of the crop to do so profitably.

Declarations

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Author Contribution

Nneka Chekure, Mutsengi Kufa and Mafuse Never conceptualised the project, designed it and carried the trials. Mandumbu Ronald wrote the first draft of the article. Sukati BH, Mabuza MP and Simelane VB reviewed and revised the manuscript.

Competing interests

The authors declare no competing interests

Compliance to IUCN Policy Statement

This research was done according to the IUCN policy statement on research involving species at risk of extinction with special reference to scientific collection of threatened species as approved in 1989.

Consent for publication

All authors read the manuscript and approved it for submission and publication.

Clinical trial

Not applicable

Ethics approval and consent to participate

Not applicable

Competing interests

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

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Data availability

All data generated are reported in the manuscript. However original data are available upon reasonable request to the corresponding author.

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Figures

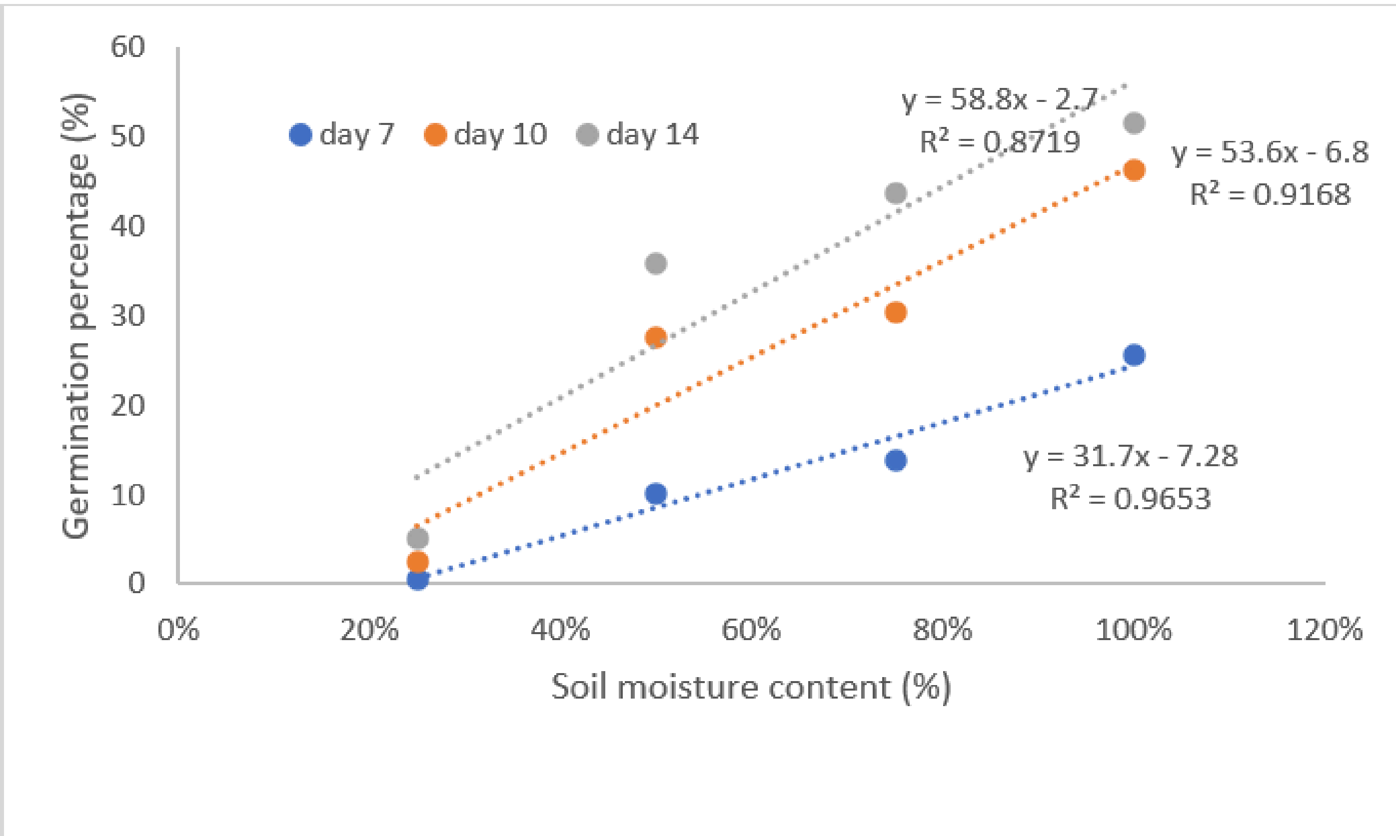

Figure 1

Effect of various soil moisture content on the germination percentage of *C. gynandra* on days 7, 10 and 14 after planting.

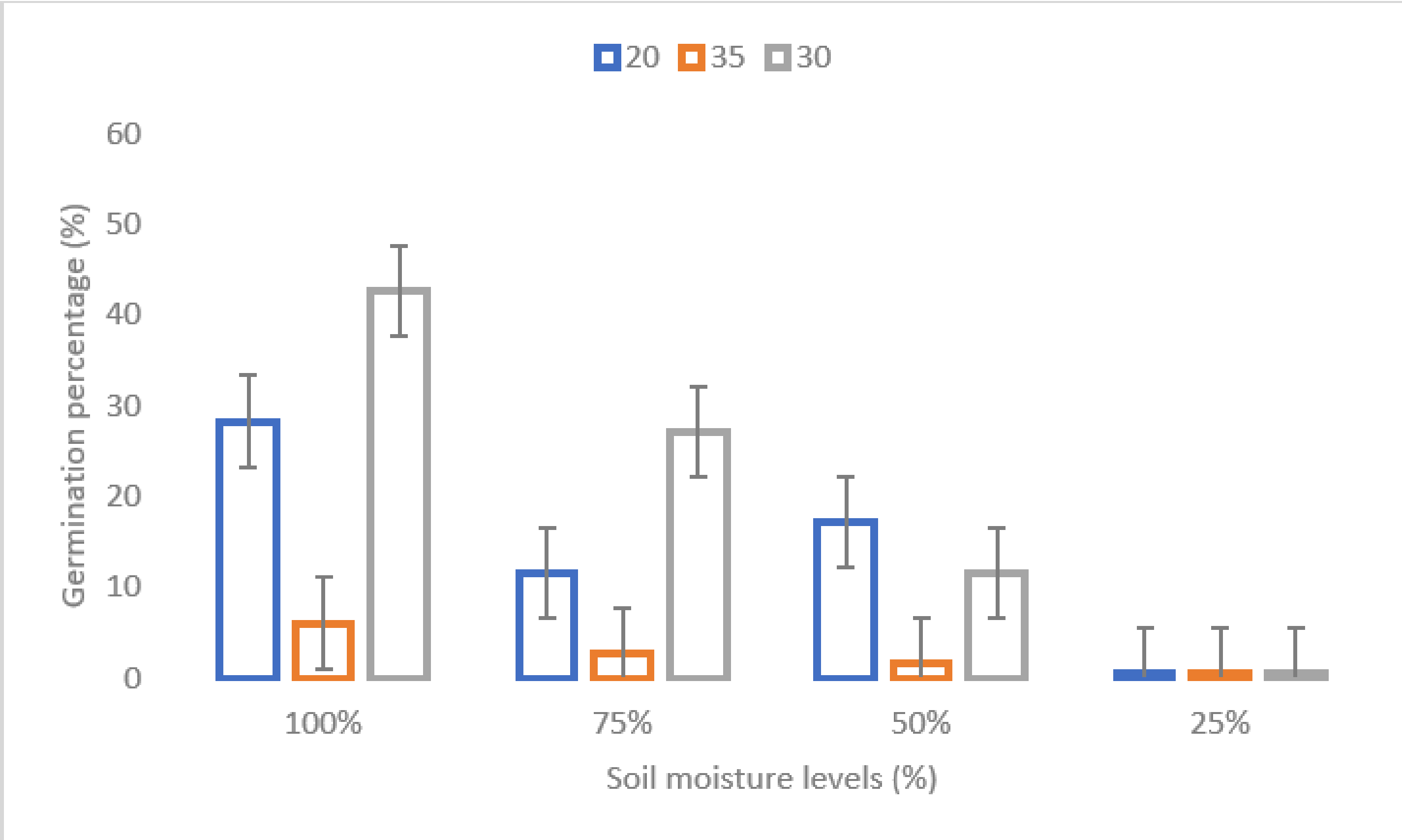

Figure 2

Interaction effects of temperature and soil moisture percentage on the germination percentage of *C. gynandra*

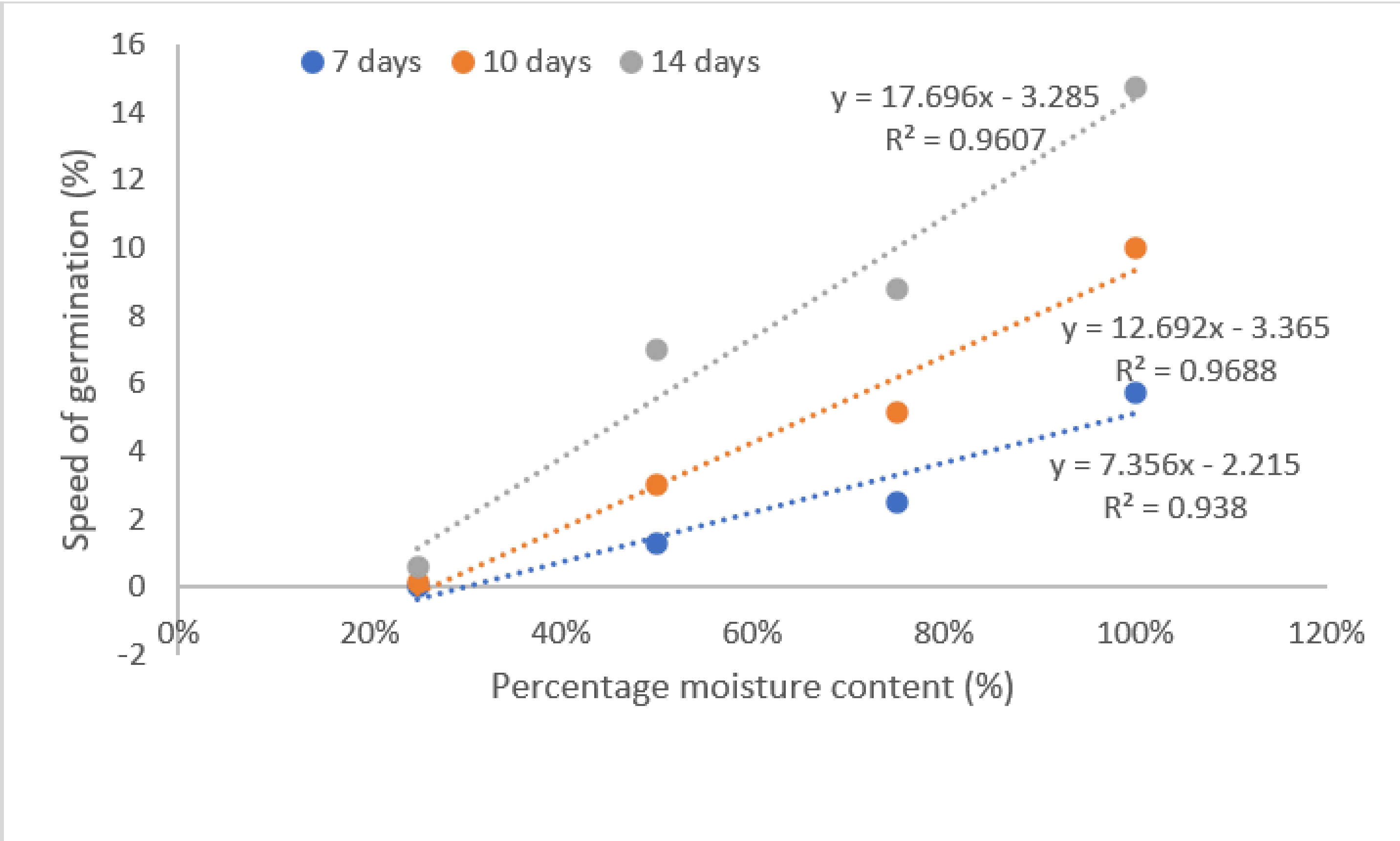

Figure 3

The relationship between soil moisture content and speed of germination of *C. gynandra* at 7, 10 and 14 days after planting

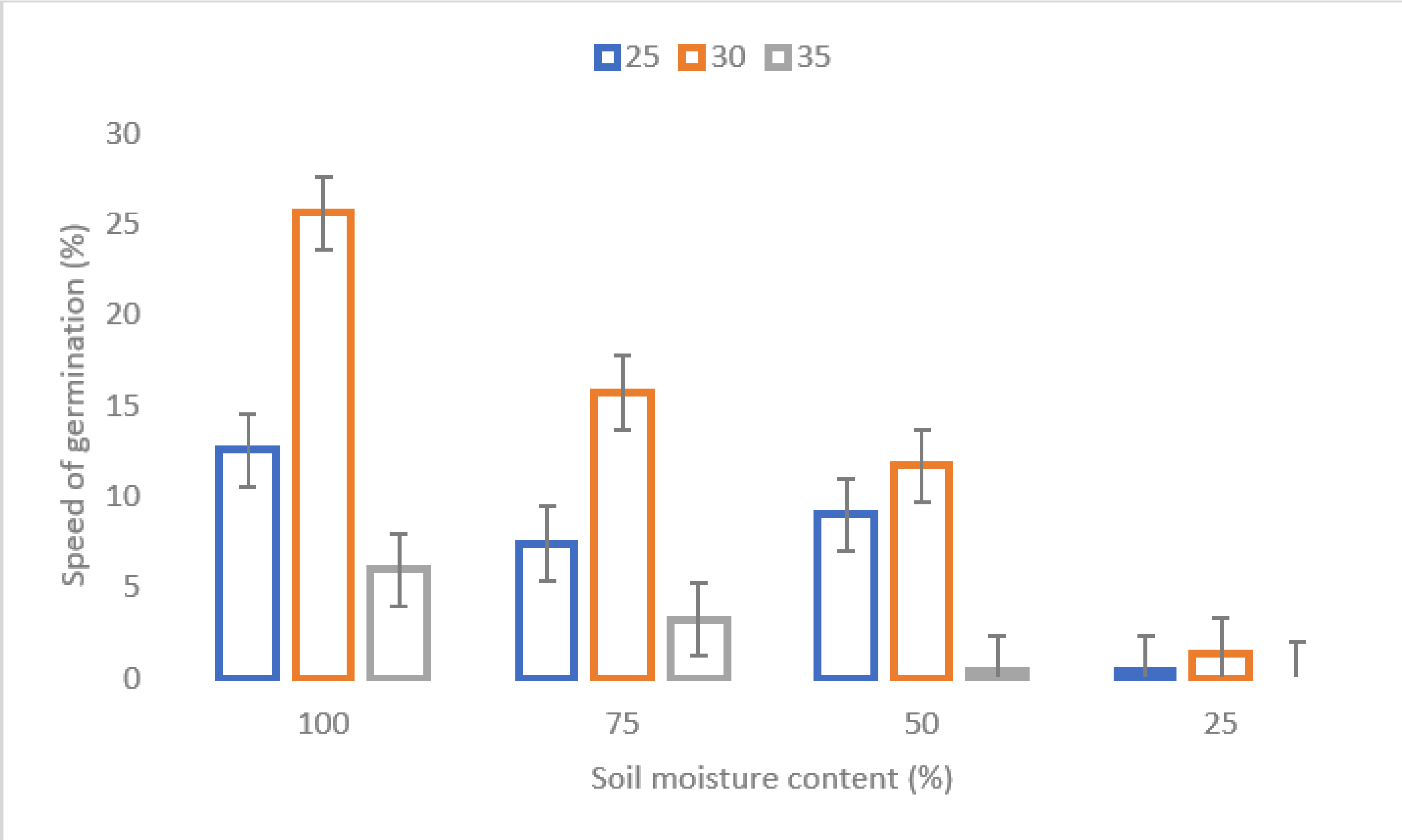

Figure 4

The interaction effects of soil moisture content and speed of germination at 25, 30 and 35^{o}C temperature

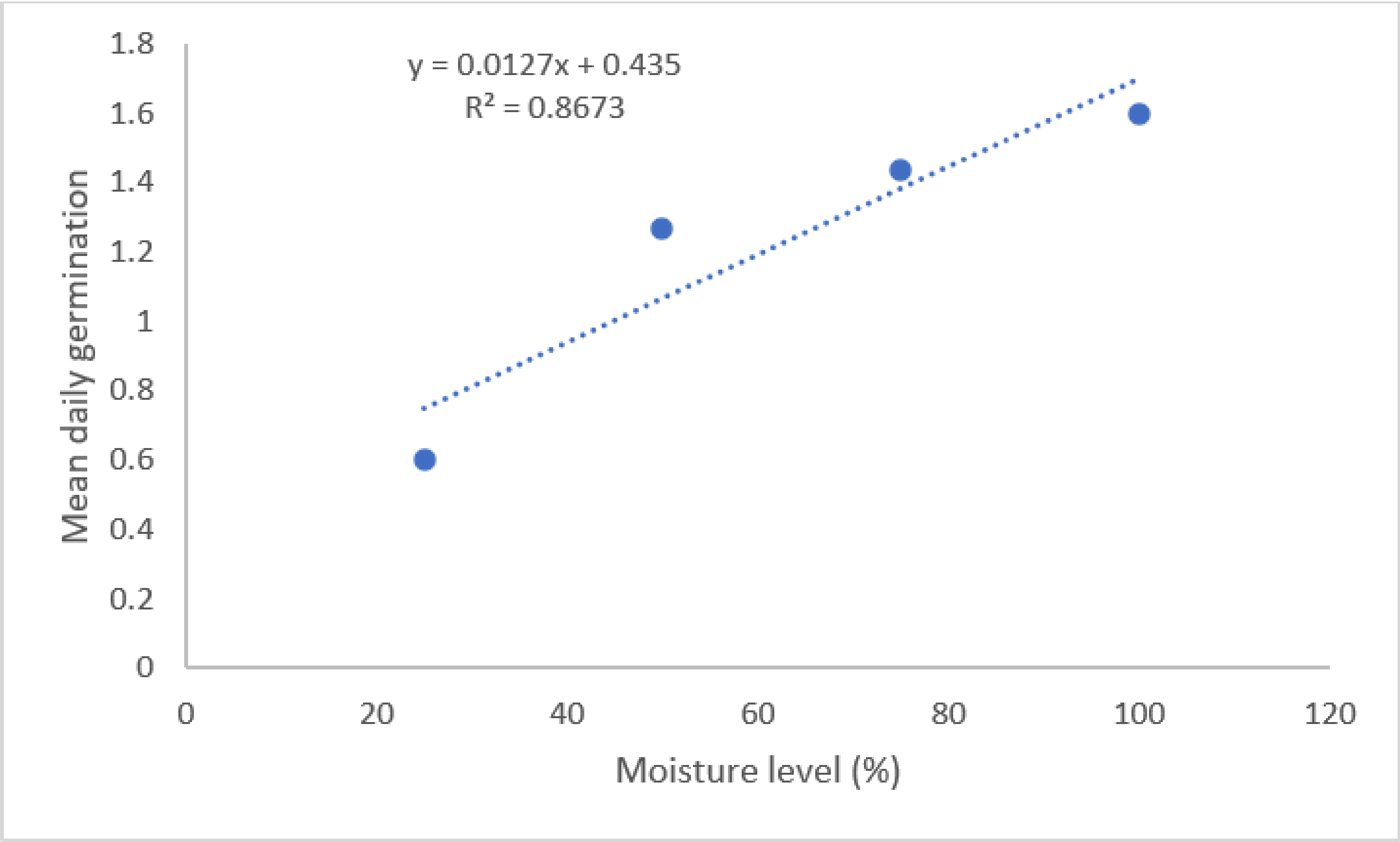

Figure 5

The relationship between mean daily germination and soil moisture level

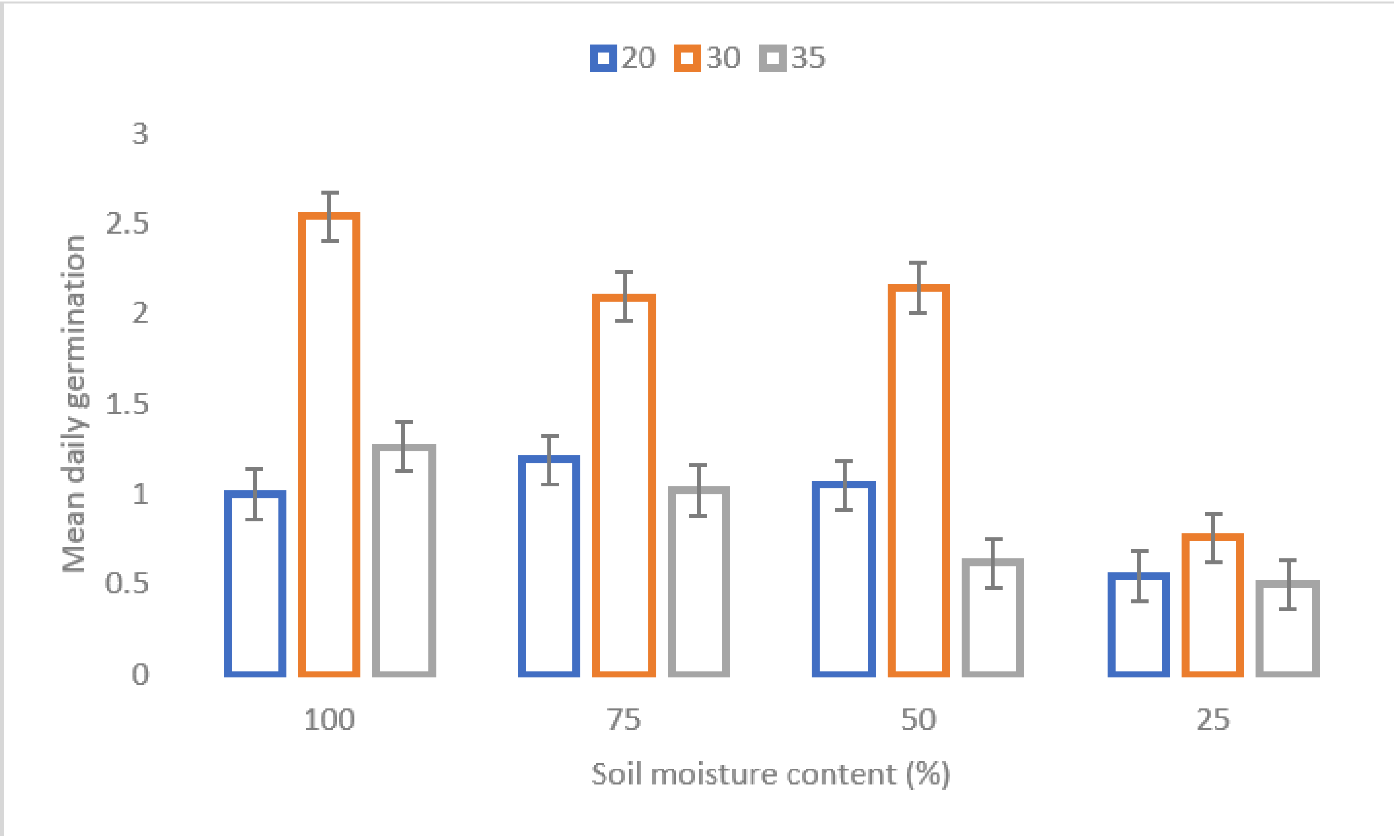

Figure 6

Interaction effects of soil moisture and temperature on mean daily germination