Original Research Article

Varying effects of field capacity watering regimes in distinct soil types on the growth characteristics of wild sorghum

Lawrence Mango[1], Morleen Nhete[2] and Gideon Walter Mutanda[3]

[1,2*]Zimbabwe Open University, Department of Agriculture Management, Bindura, Zimbabwe.
[2]Bindura University of Science Education, Department of Crop Science, Bindura, Zimbabwe.
[3]Great Zimbabwe University, Department of Physics, Geography and Environmental Science, Masvingo, Zimbabwe.

*Corresponding author: lawrencemango@gmail.com

Abstract: *Sorghum arundinaceum* Desv Stapf (wild sorghum) is spreading rapidly in Zimbabwe's farming communities. An experiment was carried out at Bindura University of Science Education to assess the plasticity of wild sorghum in response to 25%, 50%, 75% and 100% field capacity (FC) watering regimes in different soils. The experiment was laid out in a complete randomised design (CRD) with three replications. Soil samples were sieved and thoroughly mixed before pot filling. Plant height was measured using a meter rule, and leaf number and tiller numbers were physically counted at two weeks' intervals. Dry matter was measured at the end of the experiment using the oven dry matter determination method. Clay soils gave significantly higher (P<0.05) emergence percentage of 76.7% whilst sand soil had the least emergence percentage of 60.8%. Shortest plants of 34.67cm with three leaves and three tillers were observed in 25% field capacity watering regime and the tallest (42.64cm) plants with four leaves and three tillers were observed in 100% field capacity watering regime at 12 weeks after crop emergence (WACE). Loam soil gave significantly (P<0.05) taller plants (40.35cm) but had statistically similar number of leaves and tillers with those in sand and clay soil. The mean dry weight of the aboveground parts was 9.40g and was significantly higher (P<0.05) at 100% field capacity whereas 25% field capacity gave significantly lower (P<0.05) dry weight of 2.74g. Loam soil gave significantly higher dry weight of the above ground parts (P<0.05) of 7.55g whilst sand soil had significantly lower dry weight of 4.78g. The dry weight of roots gave a rather different trend, showing significantly higher dry weight of the roots in 75% FC with 16.69g whereas least dry weight of 11.05g was observed in 25% FC. Clay soil gave the least dry weight of roots of 11.04g whilst the highest dry weight was observed in loam soil with 18.57g. In conclusion, morphological plasticity was depicted in wild sorghum in varying watering regimes and different soil types. Farmers are encouraged to subdue the spread and establishment of wild sorghum in their cropping fields.

Keywords: Dry matter; field capacity; plasticity; smallholder farmers; soil types; wild sorghum

Citation: Mango et al., 2022. Varying effects of field capacity watering regimes in distinct soil types on the growth characteristics of wild sorghum. Octa J. Biosci. Vol. 10 (1):62-75

Received: 04/01/2022
Revised: 01/6/2022
Accepted: 25/6/2022
Published: 30/6/2022

1. Introduction

Food shortages in Sub-Saharan Africa have been attributed to many factors that include; crop yield losses caused by poor weed control strategies in smallholder farming communities (Matusso et al., 2014) among a myriad of other causes. Most mechanical (tillage systems) and chemical (herbicides) technologies available in weed control are usually not readily affordable to the smallholder farmers in Africa (Lee-Smith et al., 2019; Matusso et al., 2014) due to the costs attached to their implementation. Weeds compete successfully with crops for water, nutrients, sunlight and other growth limiting resources and this result in total crop failure, with some farmers being forced to abandon their crop fields due to weed infestation (Mavunganidze et al., 2014, 2016). In Zimbabwe's smallholder farming communities, weeding process is reported to consume about 50% of the available agricultural time (Chatizwa & Nazare, 2000; Lee-Smith et al., 2019). Most smallholder farmers (SHF) have adopted hoe weeding which is considered as cheap but slow, inefficient, cumbersome and labour intensive (Lee & Thierfelder, 2017). Timeliness in weed control is not adhered to and that results in serious yield losses.

Wild sorghum is a tall C4 annual weed that can behave as a perennial when environmental and climatic conditions are favorable (Jabran & Chauhan, 2018; Scott McElroy & Bhowmik, 2013). It is a tropical grass that grows in semi-arid and arid regions especially in disturbed, fertile and moist soils. According to Kanatas et al., (2021) wild sorghum is a progenitor of sorghum bicolor (cultivated grain sorghum) and is sexually compatible with other sorghum species. Wild sorghum has many tillers with short pubescence that are capable of producing seed contributing to its high seed production (Sotomayor-Ríos & Weibel, 2018). The growth production of wild sorghum is greatly influenced by the effect of field capacity watering regime and distinct soil types. The wild sorghum produces small grains that shatter from the head and one head can produce up to 300 seeds (Kanatas et al., 2021). Most farmers fail to achieve effective weed management and control due to lack of the biological and ecological understanding of the weeds. According to Diamond & Martin (2021) plasticity has greatly contributed to the persistence of weeds in heterogeneous soil and climatic growth conditions. However, there is need to identify and recognize physiological traits that lead to the long persistence of weeds in agro-ecosystems.

Weeds possess plasticity characteristics in their phenotypes as a respond to field capacity watering regime and soil physical conditions. Phenotypic plasticity is the ability of plant species to express a single genotype in a multiple phenotypic response to different environmental conditions (Albecker et al., 2022). Phenotypic plasticity can be conveyed graphically as a reaction norm to show the relationship between the two factors that affect the phenotype, environment and genotype (trait) (Kanatas et al., 2021). The plastic physiological responses include acclimation of various processes to environmental factors such as temperature, light and soil available moisture (Mutibvu et al., 2017). Thus reaction norms can be used to express the range of plasticity within and among populations under different soil physical conditions (Arnold et al., 2019). The relative weeds for sorghum such as *Sorghum halepense* L. Pers. (Johnson grass) and *Sorghum sudanense* (Sudan grass) were reported to be invasive in most parts of the world and also in Zimbabwe (Aruna et al., 2018; de Souza, 2018). *Sorghum arundinaceum* Desv. Stapf. (wild sorghum) has the ability to spread, establish and colonize ecosystems in a similar manner as other wild sorghum relative weeds. According to Rout et al., (2013) the plastic response of wild sorghum to different soil and environmental conditions gives it an added advantage to its invasiveness. As such, weed scientists need to build knowledge on plasticity characteristics of weeds so that possible geographical distribution zones can be identified (MacLaren et al., 2020) and develop preventive weed management and control measures. This may help in reducing the problems associated with weed management and enhance crop production in the smallholder farming communities of Zimbabwe.

2. Materials and Methods

2.1 Description of Study Site

The experiment was carried out at Bindura University Astra Campus ($17^0$18′ S; $31^0$19′ E) which is situated 2km south-west of Bindura town along Trojan Mine road; and 87km north-east of Harare, Zimbabwe. Bindura University is in in agro-ecological region IIa which receives an annual rainfall range of about 750mm to 900mm with summer average temperature ranging from 25ºC to 30ºC.

2.2 Experimental Design

A factorial experiment was laid out in a Complete Randomised Design (CRD) with twelve treatments replicated three times (Table 1). The first factor was the soil type with three different soil physical property conditions; sand, loam and clay. The second factor was water management regime with four levels of watering at field capacity; 25%, 50%, 75% and 100%.

Seeds of wild sorghum were provided by the Weed Research Team from Henderson Research Institute where the local Mazowe ecotype of wild sorghum is found. Sandy soil was collected from Madziwa communal area which is 50km north of Bindura town along Mt Darwin road; loam soil was collected from Manhenga communal area 20km south of Bindura town along Domboshava road and clay soil was collected from Bindura University farm which is located 10km east of Bindura town.

Table 1. Experimental Procedure showing treatment combinations

Soil Type	**Field Capacity Watering Regime (%)**			
	25%	50%	75%	100%
Sand (S)	S25	S50	S75	S100
Loam (L)	L25	L50	L75	L100
Clay (C)	C25	C50	C75	C100

2.3 Pot filling and Seeds Sowing

All pots were filled with respective soil types and were arranged as in table 1 above. Equal number of wild sorghum seeds were sown in each pot.

2.4 Wild Sorghum Management

Wild sorghum plants were monitored and inspected regularly for insect pests and diseases. Weeding was done by hand pulling in all pots as soon as the weeds emerged to ensure that only wild sorghum plants were left growing. Watering was done to the respective field capacity and as per crop watering requirement. Crop water requirement was calculated as in the equation below:

Crop water requirement = $ET_o \times K_c$ (Ewaid et al., 2019). (1)

The crop evapotranspiration, ET_o, was calculated with daily evaporation and K pan values as below:

$ET_o = E_o \times E$ pan (SreeMaheswari & Jyothy, 2017). (2)

Where:

ET_o is reference crop evapotranspiration

K pan is the pan coefficient

E_o is the pan evaporation

The pan coefficient of 0.70 was used. The data for daily evaporation (E_o) from the class A evaporation pan that was used to calculate reference evapotranspiration (ET_o) was obtained from the Kutsaga Seeds Tobacco Planning Diary (2018/2019). The E_o values used were from Shamva Research Station which is in the same natural region with Bindura town where the experiment was carried out (Table 2).

Table 2. Mean daily E_o (mm/day), ET_o (mm/day), K_c and ET_{crop} values

Month	E_o (mm/day)	ET_o(mm/day)	K_c	ET_{crop}
August	4.8	3.36	0.40	1.34
September	6.5	4.55	0.70	3.19
October	7.4	5.18	0.80	5.31
November	7.2	5.04	0.95	5.04
December	5.7	3.99	1.00	5.28

The crop water requirement was used to calculate irrigation frequency after the available soil moisture was determined. The crop water requirement was calculated using the formula:

$$Et_c = ET_o \times K_c \quad (3)$$

Where:

Et_c is the crop water requirement

ET_o is the reference evapotranspiration (mm/day)

K_c is the crop coefficient

2.5 Determination of Field Capacity

At the time of pot filling, moisture content of soil at field capacity was gravimetrically determined by watering the pots filled with soil to flooding and the pots were left for overnight. The air dry weight of the soil samples and the wet weight after drainage overnight were recorded.

Weight of water at field capacity = Weight of wet soil (g) -Weight of air dry soil (g). (4)

2.6 Determination of Irrigation Frequency

Before calculating the irrigation frequency, the amount of water applied at respective field capacities was converted from millilitres to millimetres of water equivalent to wet a depth of soil with the water applied in the respective soil. This was done by considering the amount of water equivalent to wet a square metre of soil at a depth of one millimetre. Simple proportion was used to determine the depth of water to wet the soil at the total surface area of the pots. The total surface area of the pots was uniform in all plastic pots and was calculated as πr^2.

The irrigation frequency was calculated using the formula:

$$IF = \underline{ASM} \quad (5)$$

ET_c

Where:

IF is the irrigation frequency

ASM is the available soil moisture

Et_c is the crop water requirement

The available soil moisture was obtained by using the following formula:

$$ASM = SM\ total \times RZD \times D \quad (6)$$

Where;

SM total is the total soil moisture (field capacity- permanent wilting point)

RZD is the effective root zone depth (cm)

D is the allowable depletion (50%)

The volumetric soil moisture content (θv) at the wilting point had dropped to around 10% for sandy soils, 15% in loam soils, and 20% in clay soils. This was used to determine the permanent wilting points for the soil samples. A 90cm effective root zone depth was used for calculating the available soil moisture.

2.7 Data Collection

Data collection was conducted every two weeks post emergence of wild sorghum. The following are the list of variables upon which research data was collected.

2.7.1 Emergence of Wild Sorghum

Data for emergence percentages were collected as soon as total emergence has occurred to all pots. This was done by counting all the visible emerged plants. Emergence percentage was calculated in all pots as:

$$\text{Percentage emergence of Wild Sorghum} = \frac{\text{Number of emerged seeds}}{\text{Total seeds sown}} \times 100\% \quad (7)$$

2.7.2 Growth of Wild Sorghum

The leaves were counted physically by considering every leaf on the plant stem and the mean number of leaves was recorded for each treatment. The mean number of leaves was recorded from 4 weeks up to 12 WACE. Mean number of tillers was recorded per each treatment every 2 WACE. Plant height was measured using measuring rulers (30cm and 100cm). A 30 cm ruler was used for younger and shorter than 30cm plants and beyond 30cm, a 1m meter rule was used. Measurements were taken from the above ground part up to the tip of the last leaf of the plant in all treatments.

2.7.3 Dry matter of Wild Sorghum

Dry matter accumulation was recorded in two categories, above ground vegetative part dry matter and below ground root part dry matter at the end of the experiment. All plants were uprooted and the roots were washed to remove all the soil attached on them.

Fresh weight was obtained before putting the plant materials in an oven at 72°C for 48 hours. After oven drying the plant materials were weighed and the dry weight was recorded.

2.8 Statistical Analysis

The results were subjected to analysis of variance using Genstat Discovery 4th Edition 10.0.12 and treatment means were separated using the Least Significance Difference (LSD) at 5% probability level.

3. Results and Discussion

3.1 Percentage Emergence of Wild Sorghum

Wild sorghum seeds first emerged in sand soil four days' sowing, six days in loam soil and seven days in clay soil. Emergence percentage of wild sorghum in sand soil was significantly lower ($P<0.05$) compared to both loam and clay soils (Figure 1) although emergence in loam and clay were not significantly different from one another. Seed emergence was early in sand soil probably due to the wide particle size range of the soil medium that allowed for good aeration and drainage of the seeds for quick growth and emergence (Semida et al., 2019). Early germination in sand soil could have been due to the fact that sand soils are well drained and provide good aeration thus providing enough oxygen needed for germination (Lee-Smith et al., 2019). The highest emergence percentage was observed in clay soil and this is supported by Scott McElroy & Bhowmik (2013) who revealed that seedling emergence was improved with finer soil aggregate size in the nursery. In this study, percentage emergence proliferated with the increase in clay content in the soil. However, Aruna et al., (2018) reported that the late emergence of the wild sorghum seeds in clay soil may be attributed to poor aeration which may deter early seedling emergence.

On the contrary to the results found in this study, El-Darier & Youssef (2000) found the highest germination percentage in sand soil, followed by clay soil and loam soil had the least germination percentage. The ability of this weed to germinate in all soil types indicates that this weed has widespread geographical distribution as it is able to overcome environmental constraints. Mandumbu et al., (2012) reported that weeds which are widely distributed geographically are highly plastic. Plastic weeds have great capacity of resisting environmental selection pressures such as soil conditions and drought, and they become successful invaders in many localities (Tibugari et al., 2020).

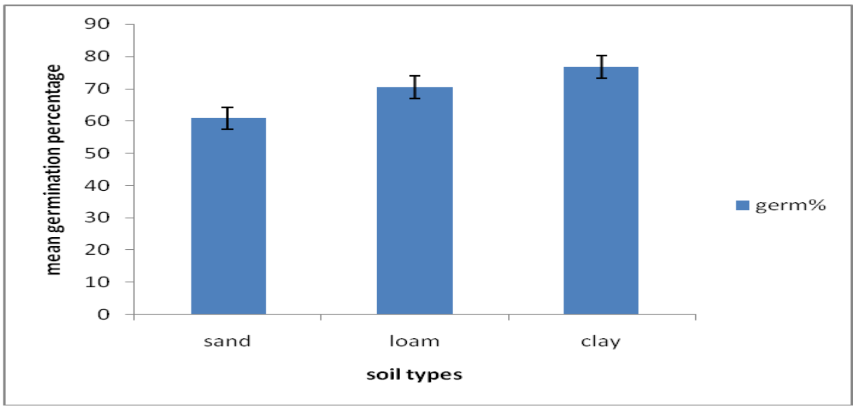


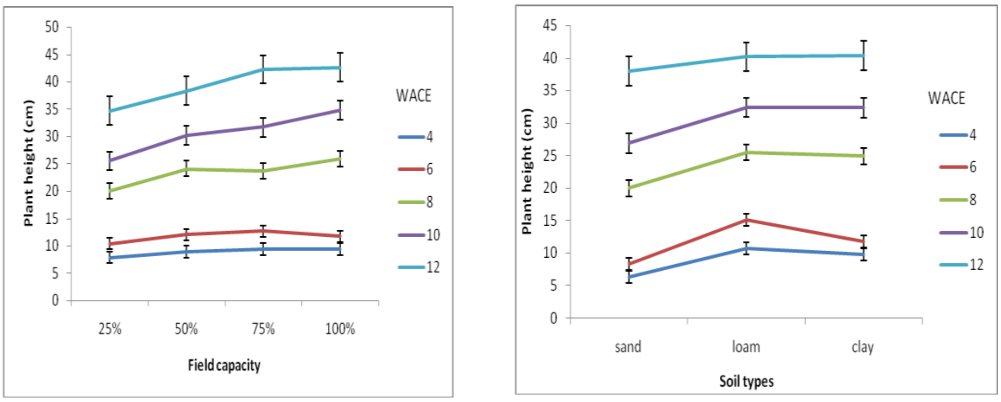
Figure 1. Percentage emergence of wild sorghum in sand, loam and clay soil. Means were separated by standard error bars.

3.2 Plant Height of Wild Sorghum

The reaction norms for plant height show that from 8 to 12 WACE there was plasticity in 25%, 50% and 75% field capacity watering regime and very low plasticity at 100% field capacity watering regime (Figure 2a). The plant height was also affected by different soil types. There was high plasticity at 4 and 6 WACE in sand and clay soil with loam soil showing no plasticity. From 8 to 12 WACE there was low plasticity in clay soil but great plasticity in sand soil whilst loam soil showed no plasticity (Figure 2b). Plant height was significantly different ($P<0.05$) in all soil types from week 4 to week 10. Week 12 showed no significant difference ($P>0.05$) in mean plant height of wild sorghum among all the soil types. Sandy soil had significantly shorter plants as compared to loam and clay soil types in all the weeks of post emergence.

The low plant height observed at 25% field capacity could be due to the fact that water stress affects elongation and expansion growth (Shakeel et al., 2011). In other crop plants such as soybean, stem length was found to decrease in water stress condition (Anjum et al., 2017). In other studies, plant height was reduced by 25% in water stressed citrus seedlings (Shakeel et al., 2011), stem length was also significantly low under water stress in *Irish potato* (Ramírez et al., 2015), *Abelmoschus esculentus* (Sankar et al., 2008), *Vigna unguiculata* (Mellouk et al., 2017), soybean (Vasconcelos et al., 2009) and parsely *Petroselinum crispum* (Corrêa Filho et al., 2018).

Although it is evident that plant growth is greatly affected by water stress conditions at the early initial stages, wild sorghum showed no significant difference in mean plant height at 4 and 6 WACE. This could be attributed to its tolerance to water stress conditions at initial growth stages that enable it survive under these severe conditions. Sorghum species have great ability of drought tolerance and high water use efficiency with several adaptive mechanisms such as; dense, deep penetrating root system, leaf rolling and stomatal closure to reduce transpiration, waxy leaf cuticles and the ability to reduce metabolic processes to near dormancy in water stress environments (Aruna et al., 2018; Shakeel et al., 2011). This could have also contributed to the non-significant differences in plant height at 4 and 6 WACE.



2a **2b**

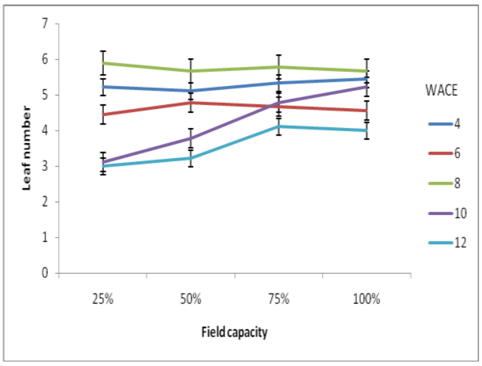
(2a) Reaction norms for plant height in different field capacity watering regimes. (**2b)** Reaction norms for plant height in different soil types

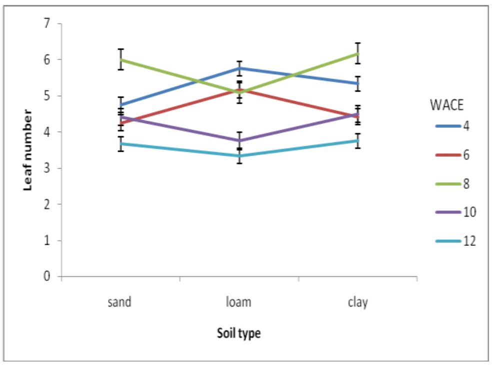
3.3 Number of Leaves of Wild Sorghum

There was great plasticity for leaf number at 10 and 12 WACE in 25%, 50% and 75% field capacity watering regimes with low plasticity in 100% field capacity watering regime. From 4 to 8 WACE there was low plasticity in leaf number in 25%, 50% and 75% field capacity watering regime with no plasticity at 100% field capacity watering regime (Figure 3a). There was high plasticity in leaf number at 8 and 10 WACE in sand and clay soil with low plasticity in loam soil. At 12 WACE there was low plasticity in leaf number in all soil types. However, at 4 and 6 WACE, leaf number was highly plastic in loam soil as compared to sand and clay soil (Figure 3b).

Leaf number was greatly reduced by low water at field capacity indicating the significant influence of water to leaf production. Results of this study are supported by findings by Ochieng et al., (2021) in Kenya and studies by Hariprasnna & Patil (2015) in India. A study by Bhatt and Srinivasa Rao, (2005) showed that there was great leaf senescence under low water field conditions for *Amaranthus. esculentus.* This increased leaf senescence in plants under water stress conditions cause decreased photosynthesis and eventually reduced plant biomass yield (Anjum et al., 2017). In some plants this senescence of leaves can be used as an adaptive response characteristic to low field capacity conditions (Volaire, 2018). Water stress to plants can also reduce leaf area, leaf growth and development in plants such as *Populus* (Surendran Nair et al., 2012), soybean (Vasconcelos et al., 2009) and many other plants (Jaleel et al., 2009).

Although it is evident that plant leaf development is affected by water stress, wild sorghum showed no significant difference in the mean number of leaves from 4 to 8 WACE. Contrary to this, Karkanis et al., (2011) found that there was reduced leaf number and leaf area in velvetleaf plants under low water field conditions. However, there was a general decrease of leaf number with the increase in water stress at 10 and 12 WACE. This is supported by the results found by Patterson (1990), when plant height, dry weight and leaf area of spurred anoda (*Anoda cristata* L.) and velvetleaf plants were reduced under water stress conditions. In another study, Mwendia et al., (2019) reported that in response to low water field conditions, C4 plants such as *Amaranthus retroflexus* L. retained greater leaf area at lower leaf water potential. Saruhan et al., (2006) also found out that *Ctenanthe setosa* (Rosc) plants showed leaf rolling response to drought related conditions.





3a **3b**

(3a) Reaction norms for leaf number in different field capacity watering regimes. (**3b**) Reaction norms for leaf number in different soil types

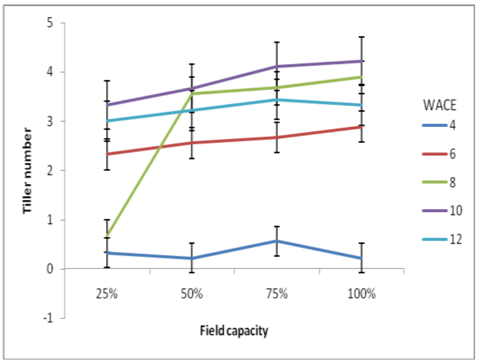
3.4 Number of tillers of Wild Sorghum

At 6, 10 and 12 WACE there was low plasticity in tiller numbers at 25%, 50% and 75% field capacity watering regimes with no plasticity in 100% field capacity watering regime. There was very high plasticity in tiller numbers at 8 WACE in 25% and 50% field capacity watering regime with low plasticity in 75% and 100% field capacity watering regime (Figure 4a). At 4 WACE there was low plasticity in all field capacity watering regimes with 75% field capacity showing high tiller numbers (Figure 4a). There was no plasticity for tiller numbers at 10 and 12 WACE in all soil types but with genetic variation among plants and without genetic variation for plasticity. At 4, 6 and 8 WACE there was high plasticity for tiller numbers in sand and clay soil whilst loam soil had low plasticity

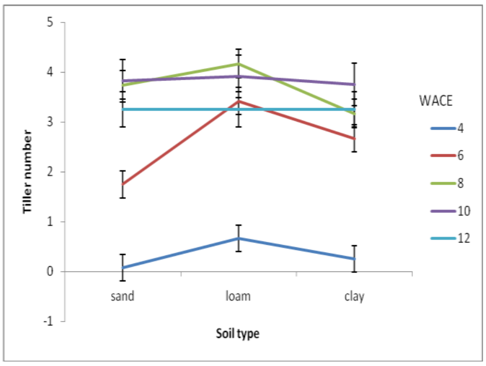
(Figure 4b). There is also genetic variation among plants with genetic variation for plasticity where the reaction norms are crossing each other.

The mean number of tillers was not significantly different (P>0.05) in all field capacity watering regimes at all the weeks of post emergence with more tillers in non-water stressed wild sorghum plants than water stressed plants. This can be due to the fact that tillering is a key component of expression of phenotypic plasticity in cereals and its response to changes in environmental conditions is important in plant adaptation to new environments (Alam et al., 2017). This is supported by Hadebe et al., (2017) who reported that tillering was found to be suitable for favourable growth conditions whereas low tillering was more desirable for stressful conditions.

Bennett et al., (2012) reported that vigorous productive tillers can restrict plant size which may increase post-anthesis water availability and grain yield in water limited environments. As such, tiller development is a complex trait that is associated with multiple genetic controls and their interaction with soil and water conditions (Alam et al., 2017). The outgrowth of tillers depends on the availability of resources and the ratio of carbohydrate supply and demand (Bennett et al., 2012; Hadebe et al., 2017) and in sorghum (Alam et al., 2014) to relate tiller appearance and to plant internal competition for resources. Some recent researches showed that tillering in few sorghum genotypes revealed that internal plant competition for resources could be responsible for most of the observed genotypic variation in maximum tiller number (Enninful, 2019; Reyes et al., 2020). Alam et al., (2014) also suggested that tillering is controlled by plant hormonal balance and water related conditions.



4a



4b

(**4a)** Reaction norms for tiller number in different field capacity watering regimes. (**4b)** Reaction norms for tiller number in different soil types

3.5 Root part and above ground part dry weight of Wild Sorghum

The interaction effect of soil type and field capacity watering regimes was not significant (P>0.05). There was significant difference (P<0.05) in mean dry weight of the above ground parts of wild sorghum at all field capacity watering regimes. The mean dry weight of the vegetative part of wild sorghum was highest at 100% field capacity watering regime and lowest at 25% field capacity. There was a general increase in dry weight as the amount of water increased (Figure 5). There was significant difference (P<0.05) in mean dry weight of the roots of wild sorghum in all field capacity watering regimes. The 75% field capacity had the highest mean dry weight and sand soil had the lowest mean dry weight of the roots of wild sorghum. The dry weight of the roots increased with the increase in the amount of water at field capacity (Figure 5).

Plant dry matter accumulation was greatly affected by water stress conditions in different soil types. There was significant difference ($P<0.05$) in the mean dry matter of wild sorghum vegetative part and root part in all field capacity watering regimes with the gradual increase of dry weight as the amount of water at field capacity increased. This could be due to the fact that the most common adverse effect of water stress to plants is the reduction in fresh and dry biomass production (Karkanis et al., 2011; Vasconcelos et al., 2009). Correa Filho et al., (2018) also reported that plant productivity under drought stress is strongly related to the process of dry matter partitioning and temporal biomass distribution. Similarly, there was reduced biomass in water stressed soybean (Shakeel et al., 2011) *Poncirus trifoliatae* seedlings (Changxun et al., 2016) common bean and gram (Udayashankar et al., 2012) and *Petroselinum crispum* (Agyare et al., 2017).

Although sorghums varieties have a tendency of developing a dense and deep penetrating root system under water stress conditions, this study showed a decrease of root dry matter in water stress conditions. This contradicted with the findings of Jaleel et al., (2009) who reported an increased root growth due to water stress in sunflower and in *Catharanthus roseus*. However, there was a decrease in root dry weight under mild and severe water stress conditions in *Populus* species (Vasconcelos et al., 2009). There was also significantly high ($P<0.05$) mean dry weight of wild sorghum vegetative part and root part in loam soil which was probably due to high water holding capacity and high nutrient retention in this soil as compared to sand and clay soil (Prasad & Staggenborg, 2009). In a study by Oyinlola and Jinadu (2012), tomato plants produced the highest fruit weights and dry matter yield under loam soil and there was no significant difference in the dry matter yield obtained in sand and clay soil. These findings are consistent with the results for both vegetative and root part dry matter of wild sorghum in this study.

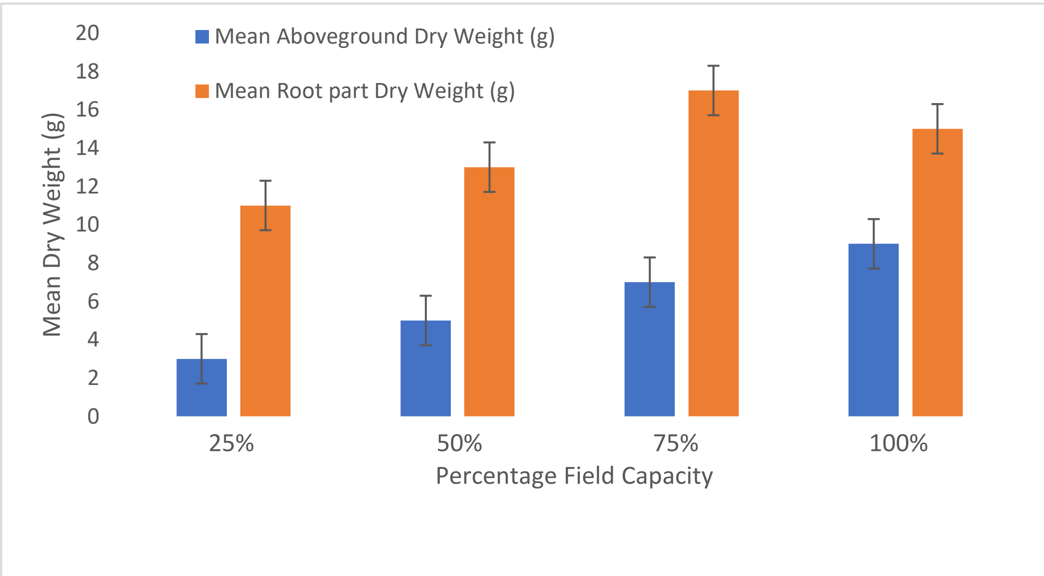


Figure 5. Mean above ground and root part dry weight of wild sorghum in different field capacity watering regimes. Means were separated by standard error bars.

4. Conclusions

The plant parts of wild sorghum showed variable growth in every treatment with respect to the varying field capacity watering regimes and soil types. Plant height, leaf number, tiller number and dry matter were significantly lower under low water field capacity conditions in all the soil types. The percentage emergence of wild sorghum seeds was affected by soil type (sandy, loam and clay). In response to the varying watering regimes in different soil types, the wild sorghum showed phenotypic plasticity. Wild sorghum has the great ability to germinate, grow and establish under heterogeneous soil and environmental conditions. Sandy soil with low field water capacity as well as clay and loam soils with high field water capacity; have shown to be possible habitats of wild sorghum. It can also be concluded that wild sorghum can spread very fast and cause great problems in high rainfall areas. Farmers are encouraged to avoid introductions of wild sorghum species in cropping fields due to their high plasticity characteristics of fast spreading and establishment. Weed scientists are also recommended to continue researching on weed biology and ecology that help in weed control and management.

Acknowledgments: We would like to thank Bindura University of Science Education management and staff for allowing us to conduct the research at the University, provision of clay soil and their assistance in plant dry matter determination. We are thankful to the Weed Research Team at Henderson Research Institute for their support in the provision of relevant information, plastic pots and seeds of *Sorghum arundinaceum* Desv Stapf. Similarly, we are grateful to Shamva Research Station for the provision of relevant information for this study. Special thanks to Madziwa and Manhenga communal areas for allowing us to abstract sand and loam soils respectively from their communities.

Author Contributions: All authors contributed to developing the overall experimental process and pooled resources for this study. Conceptualization, Morleen Nhete; methodology, Morleen Nhete, Gideon Walter Mutanda and Lawrence Mango; data curation, Morleen Nhete and Lawrence Mango; formal analysis, Morleen Nhete and Lawrence Mango; writing—original draft preparation, Gideon Walter Mutanda and Lawrence Mango; editing, Lawrence Mango; review, all authors. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

Agyare, C., Appiah, T., Boakye, Y. D., & Apenteng, J. A. (2017). Petroselinum crispum: A review. *Medicinal Spices and Vegetables from Africa*, 527–547.

Alam, M. M., Hammer, G. L., Van Oosterom, E. J., Cruickshank, A. W., Hunt, C. H., & Jordan, D. R. (2014). A physiological framework to explain genetic and environmental regulation of tillering in sorghum. *New Phytologist*, *203*(1), 155–167.

Alam, M. M., van Oosterom, E. J., Cruickshank, A. W., Jordan, D. R., & Hammer, G. L. (2017). Predicting tillering of diverse sorghum germplasm across environments. *Crop Science*, *57*(1), 78–87.

Albecker, M. A., Trussell, G. C., & Lotterhos, K. E. (2022). A novel analytical framework to quantify co-gradient and countergradient variation. *Ecology Letters*.

Anjum, S. A., Ashraf, U., Zohaib, A., Tanveer, M., Naeem, M., Ali, I., Tabassum, T., & Nazir, U. (2017). Growth and development responses of crop plants under drought stress: A review. *Zemdirbyste*, *104*(3), 267–276.

Arnold, P. A., Kruuk, L. E., & Nicotra, A. B. (2019). How to analyse plant phenotypic plasticity in response to a changing climate. *New Phytologist*, *222*(3), 1235–1241.

Aruna, C., Visarada, K., Bhat, B. V., & Tonapi, V. A. (2018). *Breeding sorghum for diverse end uses*. Woodhead Publishing.

Bennett, D., Reynolds, M., Mullan, D., Izanloo, A., Kuchel, H., Langridge, P., & Schnurbusch, T. (2012). Detection of two major grain yield QTL in bread wheat (Triticum aestivum L.) under heat, drought and high yield potential environments. *Theoretical and Applied Genetics*, *125*(7), 1473–1485.

Bhatt, R., & Rao, N. S. (2005). Influence of pod load on response of okra to water stress. *Indian Journal of Plant Physiology*, *10*(1), 54.

Changxun, G., Zhiyong, P., & Shu'ang, P. (2016). Effect of biochar on the growth of Poncirus trifoliata (L.) Raf. Seedlings in Gannan acidic red soil. *Soil Science and Plant Nutrition*, *62*(2), 194–200.

Chatizwa, I., & Nazare, R. M. (2000). Animal power for weed control: Experiences in Zimbabwe. *Animal Power for Weed Control. A Resource Book of the Animal Traction Network for Eastern and Southern Africa (ATNESA) Harare, Zimbabwe: Intermediate Technology Publications, London*.

Corrêa Filho, L. C., Martinazzo, A. P., de Souza Teodoro, C. E., & Vivès, L. (2018). Microbiological quality and essential oil of parsley (Petroselinum crispum) submitted to the hygienizing and drying process. *Industrial Crops and Products*, *114*, 180–184.

de Souza, M. F. (2018). *Impact of Temperature, Plant Species, and Sorghum Cultivar on the Population Dynamics of Melanaphis Sacchari*. Louisiana State University and Agricultural & Mechanical College.

Diamond, S. E., & Martin, R. A. (2021). Buying time: Plasticity and population persistence. In *Phenotypic plasticity & evolution* (pp. 185–209). CRC Press.

El-Darier, S., & Youssef, R. (2000). Effect of soil type, salinity, and allelochemicals on germination and seedling growth of a medicinal plant Lepidium sativum L. *Annals of Applied Biology*, *136*(3), 273–279.

Enninful, R. (2019). *Physiological characterization of parents of sorghum mapping populations exposed to water-deficit stress*. Kansas State University.

Ewaid, S. H., Abed, S. A., & Al-Ansari, N. (2019). Crop water requirements and irrigation schedules for some major crops in Southern Iraq. *Water*, *11*(4), 756.

Hadebe, S., Modi, A., & Mabhaudhi, T. (2017). Drought tolerance and water use of cereal crops: A focus on sorghum as a food security crop in sub-Saharan Africa. *Journal of Agronomy and Crop Science*, *203*(3), 177–191.

Hariprasanna, K., & Patil, J. (2015). Sorghum: Origin, classification, biology and improvement. In *Sorghum molecular breeding* (pp. 3–20). Springer.

Jabran, K., & Chauhan, B. S. (2018). *Non-chemical weed control*. Academic Press.

Jaleel, C. A., Manivannan, P., Wahid, A., Farooq, M., Al-Juburi, H. J., Somasundaram, R., & Panneerselvam, R. (2009). Drought stress in plants: A review on morphological characteristics and pigments composition. *Int. J. Agric. Biol*, *11*(1), 100–105.

Kanatas, P., Gazoulis, I., Zannopoulos, S., Tataridas, A., Tsekoura, A., Antonopoulos, N., & Travlos, I. (2021). Shattercane (Sorghum bicolor (L.) Moench Subsp. Drummondii) and Weedy Sunflower (Helianthus annuus L.)—Crop Wild Relatives (CWRs) as Weeds in Agriculture. *Diversity*, *13*(10), 463.

Karkanis, A., Bilalis, D., & Efthimiadou, A. (2011). Architectural Plasticity, Photosynthesis and Growth Responses of Velvetleaf ('Abutilon theophrasti'Medicus) Plants to Water Stress in a Semi-arid Environment. *Australian Journal of Crop Science*, *5*(4), 369–374.

Lee, N., & Thierfelder, C. (2017). Weed control under conservation agriculture in dryland smallholder farming systems of southern Africa. A review. *Agronomy for Sustainable Development*, *37*(5), 1–25.

Lee-Smith, D., Prain, G., Cofie, O., van Veenhuizen, R., & Karanja, N. (2019). Urban and peri-urban farming systems: Feeding cities and enhancing resilience. In *Farming Systems and Food Security in Africa* (pp. 504–531). Routledge.

MacLaren, C., Storkey, J., Menegat, A., Metcalfe, H., & Dehnen-Schmutz, K. (2020). An ecological future for weed science to sustain crop production and the environment. A review. *Agronomy for Sustainable Development*, *40*(4), 1–29.

Mandumbu, R., Twomlow, S., Jowah, P., Mashingaidze, N., Hove, L., & Karavina, C. (2012). Weed seed bank response to tillage and residue management in semi-arid Zimbabwe. *Archives of Phytopathology and Plant Protection*, *45*(18), 2165–2176.

Matusso, J., Mugwe, J., & Mucheru-Muna, M. (2014). Potential role of cereal-legume intercropping systems in integrated soil fertility management in smallholder farming systems of Sub-Saharan Africa. *Research Journal of Agriculture and Environmental Management*, *3*(3), 162–174.

Mavunganidze, Z., Madakadze, I. C., Nyamangara, J., & Mafongoya, P. (2014). The impact of tillage system and herbicides on weed density, diversity and yield of cotton (Gossipium hirsutum L.) and maize (Zea mays L.) under the smallholder sector. *Crop Protection*, *58*, 25–32.

Mavunganidze, Z., Madakadze, I., Nyamangara, J., & Mafongoya, P. (2016). Influence of selected soil properties, soil management practices and socio-economic variables on relative weed density in a hand hoe-based conservation agriculture system. *Soil Use and Management*, *32*(3), 433–445.

Mellouk, Z., Benammar, I., Krouf, D., Goudjil, M., Okbi, M., & Malaisse, W. (2017). Antioxidant properties of the red alga Asparagopsis taxiformis collected on the North West Algerian coast. *Experimental and Therapeutic Medicine*, *13*(6), 3281–3290.

Mutibvu, T., Chimonyo, M., & Halimani, T. (2017). Physiological responses of slow-growing chickens under diurnally cycling temperature in a hot environment. *Brazilian Journal of Poultry Science*, *19*, 567–576.

Mwendia, S. W., Yunusa, I., Sindel, B., Whalley, R., & Bruhl, J. (2019). Osmotic adjustment, stomata morphology and function show contrasting responses to water stress in mesic and hydric grasses under elevated CO2 concentration. *Photosynthetica*.

Ochieng, G., Ngugi, K., Wamalwa, L. N., Manyasa, E., Muchira, N., Nyamongo, D., & Odeny, D. A. (2021). Novel sources of drought tolerance from landraces and wild sorghum relatives. *Crop Science*, *61*(1), 104–118.

Oyinlola, E., & Jinadu, S. (2012). Growth, yield and nutrient concentrations of tomato as affected by soil textures and nitrogen. *Asian Journal of Agricultural Research*, *6*(1), 39–45.

Patterson, D. T. (1990). Effects of density and species proportion on competition between spurred anoda (Anoda cristata) and velvetleaf (Abutilon theophrasti). *Weed Science*, *38*(4–5), 351–357.

Prasad, P. V., & Staggenborg, S. A. (2009). Growth and production of sorghum and millets. *Soils, Plant Growth and Crop Production*, *2*.

Ramírez, D., Rolando, J., Yactayo, W., Monneveux, P., Mares, V., & Quiroz, R. (2015). Improving potato drought tolerance through the induction of long-term water stress memory. *Plant Science*, *238*, 26–32.

Reyes, J. A. O., Carpentero, A. S., Santos, P. J. A., & Delfin, E. F. (2020). Effects of water regime, genotype, and formative stages on the agro-physiological response of sugarcane (Saccharum officinarum L.) to Drought. *Plants*, *9*(5), 661.

Rout, M. E., Chrzanowski, T. H., Smith, W. K., & Gough, L. (2013). Ecological impacts of the invasive grass Sorghum halepense on native tallgrass prairie. *Biological Invasions*, *15*(2), 327–339.

Sankar, B., Jaleel, C. A., Manivannan, P., Kishorekumar, A., Somasundaram, R., & Panneerselvam, R. (2008). Relative efficacy of water use in five varieties of Abelmoschus esculentus (L.) Moench. Under water-limited conditions. *Colloids and Surfaces B: Biointerfaces*, *62*(1), 125–129.

Saruhan, N., Turgut-Terzi, R., & Kadioglu, A. (2006). The effects of exogenous polyamines on some biochemical changes during drought stress in Ctenanthe setosa (Rosc.) Eichler. *Acta Biologica Hungarica*, *57*(2), 221–229.

Scott McElroy, J., & Bhowmik, P. C. (2013). Turfgrass weed management. *Turfgrass: Biology, Use, and Management*, *56*, 777–808.

Semida, W. M., Beheiry, H. R., Sétamou, M., Simpson, C. R., Abd El-Mageed, T. A., Rady, M. M., & Nelson, S. D. (2019). Biochar implications for sustainable agriculture and environment: A review. *South African Journal of Botany*, *127*, 333–347.

Shakeel, A. A., Xiao-yu, X., Long-chang, W., Muhammad, F. S., Chen, M., & Wang, L. (2011). Morphological, physiological and biochemical responses of plants to drought stress. *African Journal of Agricultural Research*, *6*(9), 2026–2032.

Sotomayor-Ríos, A., & Weibel, D. E. (2018). Grain crops. In *CRC Handbook of Tropical Food Crops* (pp. 7–26). CRC Press.

SreeMaheswari, C., & Jyothy, S. A. (2017). Evaluation of Class A pan coefficient models for estimation of reference evapotranspiration using penman-monteith method. *Int. J. Sci. Techn. Eng*, *3*, 90–93.

Surendran Nair, S., Kang, S., Zhang, X., Miguez, F. E., Izaurralde, R. C., Post, W. M., Dietze, M. C., Lynd, L. R., & Wullschleger, S. D. (2012). Bioenergy crop models: Descriptions, data requirements, and future challenges. *Gcb Bioenergy*, *4*(6), 620–633.

Tibugari, H., Marumahoko, P., Mandumbu, R., Mangosho, E., Manyeruke, N., Tivani, S., Magaya, R., & Chinwa, H. (2020). Allelopathic sorghum aqueous extracts reduce biomass of hairy beggarticks. *Cogent Biology*, *6*(1), 1810382.

Udayashankar, A., Nayaka, S. C., Niranjana, S., Mortensen, C., & Prakash, H. (2012). Immunocapture RT-PCR detection of Bean common mosaic virus and strain blackeye cowpea mosaic in common bean and black gram in India. *Archives Of Phytopathology And Plant Protection*, *45*(13), 1509–1518.

Vasconcelos, A. C. F. de, Zhang, X., Ervin, E. H., & Kiehl, J. de C. (2009). Enzymatic antioxidant responses to biostimulants in maize and soybean subjected to drought. *Scientia Agricola*, *66*, 395–402.

Volaire, F. (2018). A unified framework of plant adaptive strategies to drought: Crossing scales and disciplines. *Global Change Biology*, *24*(7), 2929–2938.