International Journal of Plant & Soil Science
11(6): 1-9, 2016; Article no.IJPSS.24731
ISSN: 2320-7035

SCIENCEDOMAIN *international*
www.sciencedomain.org

Influence of Maternal Season on Field Establishment of Sorghum Varieties Grown in Zimbabwe

N. Ngwenya[1], B. T. Manenji[1*], T. Madanzi[1], S. Kudita[2] and W. Mahohoma[1]

[1]Department of Agronomy, University of Midlands State, P. Bag 9055, Gweru, Zimbabwe.
[2]International Crop Research Institute for Semi-Arid Tropics (ICRISAT), Matopos Research Station, P.O.Box 776, Bulawayo, Zimbabwe.

Authors' contributions

This work was carried out in collaboration between all authors. Authors NN and WM designed the study, wrote the protocol, and wrote the first draft of the manuscript. Authors BTM and TM managed the literature research, and analysis of data. Author SK managed the experimental process. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2016/24731
Editor(s):
(1) Mirza Hasanuzzaman, Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.
Reviewers:
(1) Jen-yu Shieh, National Formosa University, Taiwan.
(2) Tran Dang Xuan, Hiroshima University, Japan.
Complete Peer review History: http://sciencedomain.org/review-history/15322

Original Research Article

Received 30th January 2016
Accepted 28th March 2016
Published 9th July 2016

ABSTRACT

Maternal season defined, as the prevailing environmental conditions during crop growth has been known to influence not only grain yield but also seed quality. A laboratory and field experiment were conducted in October 2014, to determine the influence of total rainfall and mean monthly temperature on germination, vigor and emergence of sorghum seeds which were harvested from three different seasons and were kept under controlled conditions. The laboratory experiment was a 3 x 3 factorial experiment laid in completely randomized block design (CRD) replicated three times. The first factor was variety (Macia, SDSL 89473 and Sima), the second factor was growing season (2004/5, 2006/7, 2007/8). A field experiment was carried out to investigate the emergence of seed materials used in the laboratory experiment. The experiment was a 3 x 3 x 3 factorial treatment structure laid out in a Randomized Complete Block Design (RCBD) with the third factor being sowing depth at 5.0, 7.5 and 10.0 cm. Seedling emergence was observed at 10 days after sowing. In the laboratory experiment it was observed that there was no significant difference ($P>0.05$) on the effects of season and variety on germination of seeds. However, there was significant difference ($P<0.001$) on seed vigor due to variety under laboratory conditions. For the

*Corresponding author: E-mail: manenjibt@gmail.com;

field experiment, there was significant interaction (P<0.001) on seedling emergence due to season, sowing depth and variety. The highest emergence for all varieties was observed at a sowing depth of 5cm. It can be concluded that maternal season, which is the season in which the seed was grown, has great influence on the vigor of seed produced under dry-land agriculture. There is need to repeat the experiment using more seed lots harvested at many different seasons in order to determine the exact optimum amount of rainfall and temperatures during the maternal season that will promote optimal germination and emergence of dry-land sorghum varieties.

Keywords: Germination; emergence; seed quality; seed vigor; dry-land sorghum; maternal effect.

1. INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is one of the major crops grown in the semi-arid regions of the world including Southern Africa. It feeds more than 300 million people in the arid and semi-arid regions of Africa and these people rely on it as their primary source of food [1]. According to Leuschner and Manthe [2] sorghum is normally grown in marginal areas located in Natural Farming Regions IV and V of Zimbabwe according to the classification of Vincent and Thomas [3]. These areas are characterized by high temperatures, and low erratic, poorly distributed rainfall of less than 650 mm per year. Characteristics of sorghum that have led to its successful production in these areas include the ability to remain dormant during drought and then resume growth when favorable conditions are experienced, leaves roll up as they wilt reducing the area of leaf exposed for transpiration, leaves and stalk contain an abundance of waxy coating which protects them from drying by reducing transpiration [4].

Despite its potential of stabilizing household food security, sorghum productivity is reported to be low in Zimbabwe with average yields of 410 kg per hectare [2]. Poor crop establishment has been identified as one of the major factors that limit production of sorghum in Zimbabwe [5]. In some studies done in Zimbabwe, it was observed that sorghum germination is highly unpredictable with seed quantities as high as 50 kg/ha resulting in zero emergence [5]. According to Chiduza [5], most of the smallholder farmers in Zimbabwe resort to planting seeds retained from previous harvest because they cannot afford to buy certified seed. Madanzi et al. [6] attributed the failure of sorghum to establish to the fact that the seeds used by the farmers are often of poor quality as they have poor germination capacity as well as vigor. Seeds of high vigor result in rapid germination, emergence, root and shoot growth during early stages of growth and such seed will be able to cope with sub-optimal conditions experienced in semi-arid tropics including Zimbabwe [7,8]. Poor seed quality limits to productivity since it gives rise to poor emergence and crop stand and thus reducing the yield [9].

The quality of the maternal season, defined as the prevailing environmental conditions during the growing period for the seed crop, has a great impact on the viability of the seed produced. Exposure of seed to intensive biotic and abiotic stresses reduces the rate of photosynthesis of the crop resulting in less assimilates being partitioned to various organs of the crop including seeds. Research has shown that exposing the mother plants to high temperature and water stress may result in the development of physiological disorders in the seeds which consequently result in poor germination, a decrease of seedling growth and poor seedling emergence [9]. Recent studies on sorghum have indicated that the impact of such stresses is more severe when they occur during the reproductive stages since they are more sensitive to moisture stress and higher temperature than vegetative stages [10]. This study was conducted to determine the effects of maternal season on germination, vigor and emergence of three common sorghum varieties (i.e. Macia, SDSL 89473 and Sima) grown in Zimbabwe.

2. MATERIALS AND METHODS

The study was carried out at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), which is located at Matopos Research Station situated 30 km out of Bulawayo town. The site lies at a latitude of 20°25’ S and longitude of 28°28’ E, at an elevation of 1 370 m above sea level. The site has red clay soils, with pH ranging from 7-8 and has a water retention percentage of between 30-40%. Temperatures are characteristic of sub-tropical areas with very high temperature during the day and very cold nights, mean summer temperatures are 36°C and summer stretches from September to March and mean rainfall of 250 mm to 350 mm [3].

2.1 Seed Lots

Three sorghum varieties (Macia, Sima and SDSL 89473) harvested at physiological maturity in three different seasons (2004/5, 2006/7, 2007/8) were used as germplasm in this experiment. The seed lots were stored at ICRISAT gene bank storage facility which keeps seed under controlled environments, thus eliminating the poor storage effect on seed vigor.

2.2 Laboratory Experiment

The laboratory experiment comprised a standard germination test and a vigor test using the high temperature accelerated aging test (AAT) method.

2.2.1 Standard germination test

Germination test of seeds from the three sorghum varieties harvested in three different seasons was done using the standard germination test method using rolled paper towels [11]. Eight sub-samples of 50 seeds of each harvested variety were placed on the upper half of moist blotter paper towels. Each towel was folded in the middle and seeds were covered completely with the lower half of the blotter paper. The papers were rolled and put in an incubator at 25℃ for 48 h. After 48 h, the blotter papers were removed and the number of germinated seedlings was observed. Germination percentage was calculated as according to [11], as follows:

$$\text{Germination \%} = \frac{\text{number of seeds that germinated}}{\text{total number of seeds in the petri dish}} * 100$$

2.2.2 Seed vigor test

Seed vigor was tested using the Accelerated Aging test. Under this test, unimbibed seeds were subjected to conditions of very high relative humidity (100%) and a high temperature of 41℃ for 72 hours so as to stimulate the aging process [12]. A normal germination test was then carried out on the aged seed according to the procedures of a standard germination test stated above. Unlike in the standard germination test, here seed germination was observed after 7 days and the germination percentages were calculated using the formula stated earlier.

2.3 Field Experiment

The field experiment was carried out to determine the effects of season on early stand establishment. The field experiment was laid out as a 3 x 3 x 3 factorial treatment structure in a randomized complete block design (RCBD) with three replicates, blocking factor being the slope. Seed from three different varieties was used (Macia, Sima and SDSL 89473) and the seed used was harvested from three different seasons (2004/5, 2006/7 and 2007/8). Seed for Macia for the 2005/6 season was insufficient for use in this study and the whole season was forfeited. To test for vigor, 100 seeds from each seed lot were planted at three different sowing depths (5, 7.5 and 10 cm). The seeds were planted in plots which comprised of two rows which were 75 cm apart with intra row spacing of 4 cm. Seeds were dribbled manually into the rows at different depths of 5, 7.5, and 10 cm and covered evenly with soil to ensure uniform germination. Emergence data was collected after from between day 7 up to day 10 after sowing, when no further emergence occurred. Seedlings that were visible above the soil surface were considered to have emerged.

2.4 Data Analysis

Analysis of variance (ANOVA) was carried out on germination percentage, vigor and emergence percentage using Genstat 14th Edition. The least significant difference (LSD) was used to separate means among various treatments at 5% level of significance.

3. RESULTS

3.1 Weather Data

Fig. 1 shows the total monthly rainfall and mean monthly temperature recorded during the three growing seasons (i.e. 2004/5, 2006/7 and 2007/8) for the sorghum seeds at Matopos Research Station. There was a lot of variation in the total monthly rainfall and mean monthly temperatures from the three growing seasons considered. Total monthly rainfall ranged from 0 mm (in May 2007) to a maximum of 274 mm (in December 2005). Total rainfall amounts received during the 2004/5, 2006/7 and 2007/8 were 875, 497 and 590 mm, respectively. Average minimum temperatures (T_{min}) ranged from 8.3 to 17.3℃; and average maximum temperatures ranged from 21 to 31.9℃.

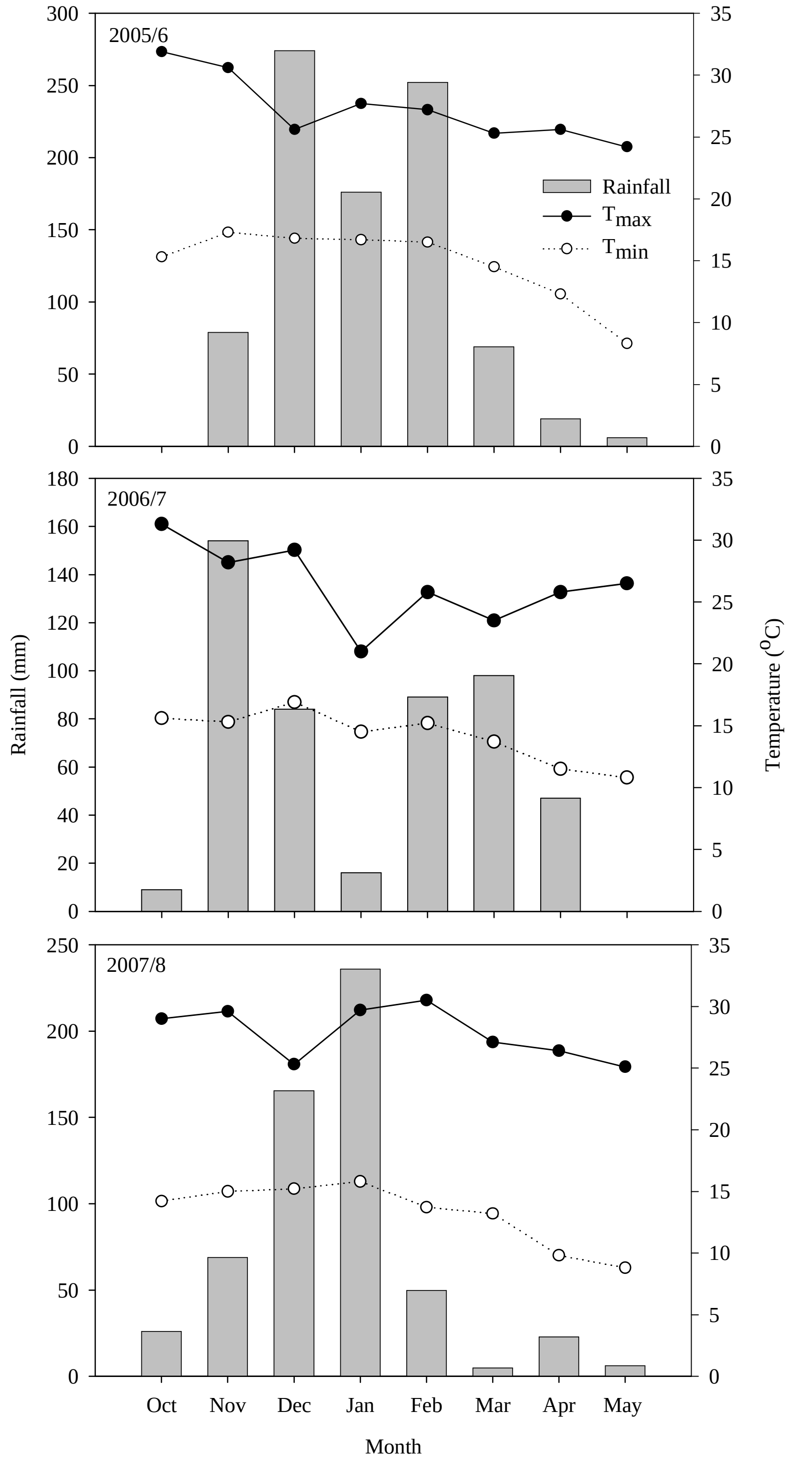

Fig. 1. Total monthly rainfall data and mean monthly temperature recorded during the three growing seasons (i.e 2004/5, 2006/7 and 2007/8) for the sorghum seeds

3.2 Influence of Maternal Season on Germination of Different Sorghum Varieties

There was a significant interaction (P<0.001) on germination between season and variety (Fig. 2). The seedlot of Macia and SDSL 89473 grown during the 2004/5 rainy season achieved high germination percentages of 96% each whereas the 2004/5 season Sima seedlot had the lowest germination of 29%. Of the seedlots grown during 2006/7 rainy season, the seedlot of SDSL 89473 achieved significantly higher germination percentage of 94% than Macia and Sima had a germination percentage of 76% and 75%, respectively (Fig. 2). The germination percentage for Macia grown during the 2006/7 rainy season was significantly lower than that attained from the seedlot which was grown during the 2004/5 rainy season while that for SDSL 89473 grown during 2006/7 was significantly higher compared to that for the 2004/5 rainy season. Among the three varieties, there was no significant difference in the germination percentage when the cultivars were grown during the 2007/8 rainy season. The individual effects of variety and season also showed significant difference (P<0.001).

3.3 Influence of Maternal Season on Seed Vigor of Different Sorghum Varieties

Fig. 3 shows that there was a significant interaction (P<0.001) on seed vigor due to season and varietal influences. Seedlots grown during the 2006/7 season had the lowest seed vigor except for SDSL 89473 which achieved a high vigor during the same season. SIMA lost its vigor due to storage with the crop grown during the 2004/5 and 2006/7 rainy seasons achieving very low germination. SDSL 89473 maintained high vigor across the seasons while Macia achieved lower vigor in the 2006/7 season only.

3.4 Influence of Maternal Season and Sowing Depth on Field Emergence of Different Sorghum Varieties

In the field experiment there was an interaction (P <0.05) between variety, sowing depth and season on the field emergence percentage observed at 10 days after planting. The 2006/7 season produced seed lots that had the highest field emergence percentage for all the three varieties followed by the seed lots produced in 2004/5 season and then 2007/8 season seeds respectively (Fig. 4). Variety Macia had the highest emergence percentage followed by SDSL 89473 and then Sima. Increasing sowing depth resulted in a decrease in seedling emergence percentage for the three varieties. The highest emergence percentage was recorded at the 5 cm sowing depth followed by 7.5 cm and then 10 cm. Overally the highest emergence percentage was observed in the variety Macia, harvested in 2006/7 and sown using a sowing depth of 5 cm.

4. DISCUSSION

Field establishment of sorghum seeds has been reported to be problematic among smallholder farmers in the semi-arid regions of Zimbabwe [13]. Such problems emanate from the fact that these farmers use retained seeds which are often of poor quality. Total rainfall amounts received during the 2004/5, 2006/7 and 2007/8 seasons were above, almost equal to and slightly below the long term mean reported by [3], respectively. Although both average maximum and minimum temperatures recorded were comparable to the long-term mean values, differences noted could have effects on sorghum seed viability.

From the results there was a significant difference due to season (P<0.001) on seed germination percentage. The total rainfall received during the growing season had a strong influence on the viability of sorghum seeds grown under dry-land farming. Rainfall amounts received in the three seasons are enough to meet crop requirements of a generic sorghum crop from germination to maturity. However, rainfall distribution is another attribute which influences seed quality. From this study it was observed that water stress at an early growth stage has little impact on the seed quality as compared to water stress during the reproductive phase as was observed in the seedlot of 2007/8 season. As such, seedlots obtained from the 2006/7 season recorded the highest vigor score and also had the highest emergence and crop stand in all the varieties, while on the other hand seed lots obtained from the 2007/8 had the lowest vigor score and poor emergence and crop stand. High rainfall during this period favors the process of seed maturation and grain filling, since there will be more water available which helps ensure high photosynthetic efficiency of the sorghum crop as well as efficient transportation of assimilates and other substances towards the seeds [14].

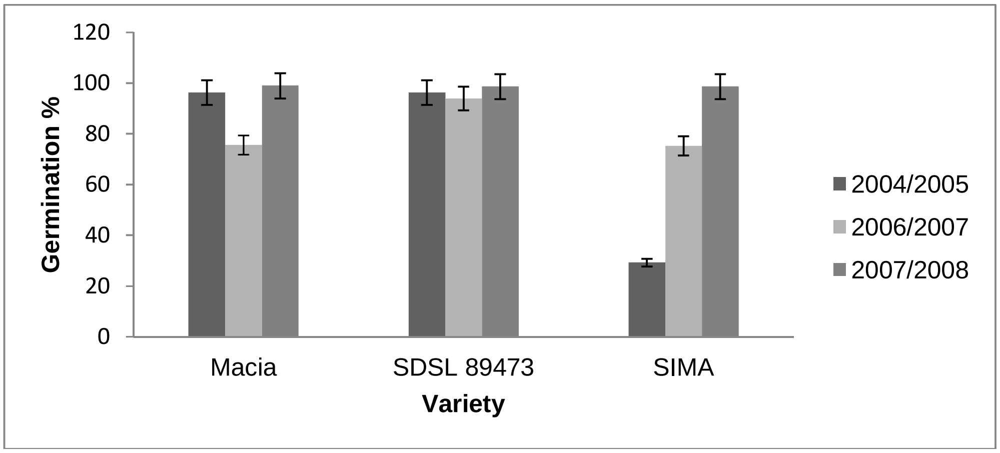

Fig. 2. Germination percentage of different sorghum varieties (Macia, SDSL 89473 and SIMA) grown in three different seasons (i.e. 2004/5, 2006/7 and 2007/8)

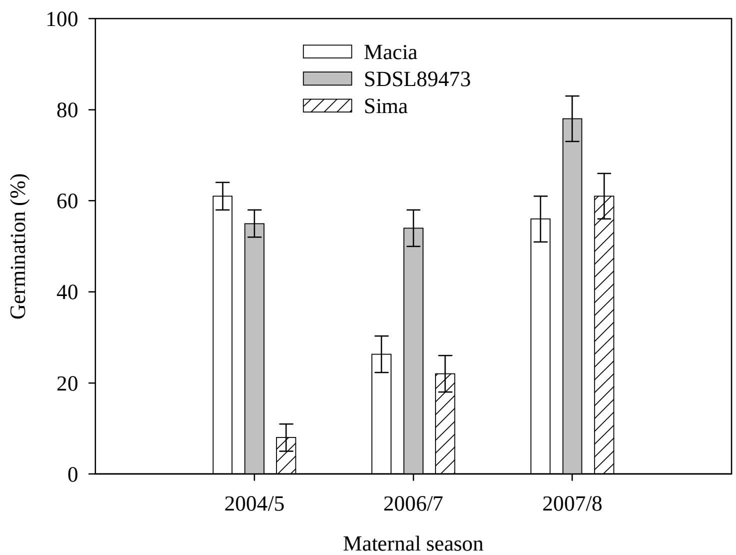

Fig. 3. Seed vigor of different sorghum varieties (Macia, SDSL 89473 and SIMA) grown in three different seasons (i.e. 2004/5, 2006/7 and 2007/8)

Besides rainfall another weather parameter that had a significant influence on sorghum seed quality in this study, was temperature. High temperatures affect many agronomic characteristics of sorghum [15] [16] [17] and reproductive aspects such as pollen production, pollen germination and seed set. According to Yamakawa et al. [9] photosynthetic rates decline when sorghum leaf temperatures exceed 33℃ resulting in limited assimilates being synthesized. These high temperatures coupled with low rainfall during the grain filling stage impairs dry matter production, and this results in forced maturity of seed thereby producing shriveled seeds thus resulting in poor grain quality [9]. Very high day temperatures in the semi-arid regions are complimented by very low temperatures during the night and sorghum is very sensitive to low temperatures and frost. If the crop is attacked by frost during the grain filling stage, the leaves dry up, this means that assimilates for grain filling will not be manufactured resulting in poor grain. Harris [18] discovered that high temperatures during the last 45 days of seed maturation for soybeans were associated with low seedling vigor.

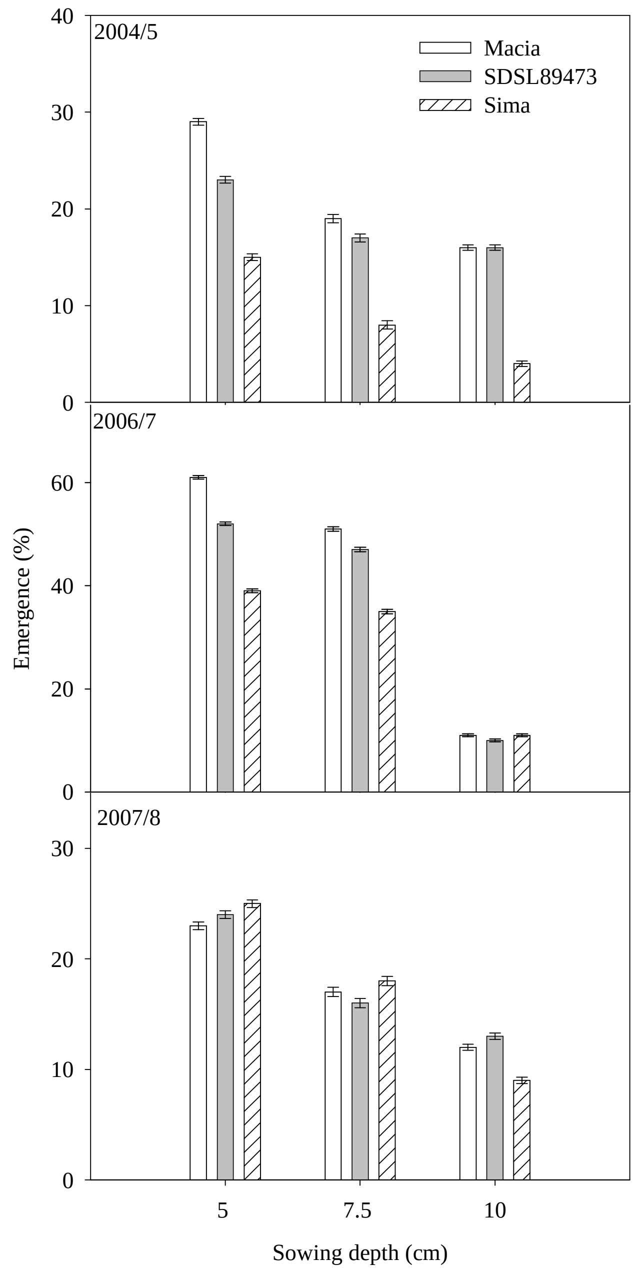

Fig. 4. Seed emergence of different sorghum varieties (Macia, SDSL 89473 and SIMA) grown in three different season (i.e. 2004/5, 2006/7 and 2007/8)

In the field experiment, there was a significant difference (P<0.001) due to planting depth on the seedling emergence and crop establishment and this is well expected. This can be attributed to a number of factors that include light, temperature, soil water content and soil compaction [16]. The highest emergence percent for all varieties was observed at shallower depths (5 and 3 cm) in all varieties despite of the season in which they were grown. This is probably due to the fact that the sorghum seed is small and would require shallow depths as recommended by Jobir and Fetene [4]. The results obtained in this study are consistent with those by Napo [19] who found out that planting depth has significant effect on seedling emergence. Jobir and Fetene [4] also found that increasing sowing depth results in reduction in germination capacity of sorghum. Lack of germination in greater depth could be because of secondary dormancy induction in seeds [20]. Seed dormancy could have been due to restriction of gas exchange with increasing depth of sowing.

Regression analysis amongst the measured parameters (i.e. germination percentage, seed vigor and emergence) against the weather parameters used to define the maternal season (i.e. rainfall and temperature) did not yield any meaningful relationships (data not shown). Such relationship can probably be used by farmers to make decisions on choosing the season from which to store sorghum seeds for planting in the later seasons. The failure of the regression analysis to yield positive results could be due to two reasons. Firstly, the data set considered here could be too small such that a reasonable trend cannot be established. Secondly, the effect of these weather variable acts on the seed simultaneously such that more detailed than simple regression are required for this purpose.

5. CONCLUSION

From this study it can be concluded that the maternal season, which is the season in which the seed was grown, has high influence on the seed produced under dry-land agriculture. It was observed that high temperatures and water stress during seed development give rise to seeds with poor vigor that would result in low emergence and hence poor crop stand. It can also be concluded that increase in sowing depth may result in a reduction in seeds' capacity to emerge. The data in this work is not enough to do the analysis that can come up with guidelines for farmers to choose which season to choose sorghum seed for planting. More experiments of this nature should be carried out to establish such guidelines with the possibility of developing a decision making tool.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Paterson AH. Genomics of sorghum. Int J of Plant Genomics6 pages; 2008:6. Article ID 362451. DOI:10.1155/2008/362451.
2. Leuschner K, Manth CS. Drought tolerant crops for Southern Africa. Proceedings of the SADC/ICRISAT Regional sorghum and pearl millet workshop; 1994. Gaborone, Botswana;1996.
3. Vincent V, Thomas RG. Agro ecological survey of Southern Rhodesia. Government Printers, Salisbury. 1961;124.
4. Jobir K, Fetene M. Effect of traditional storage and soil depth on germination capacity of sorghum (*Sorghum bicolor* (L.) Moench) seeds. Agric and Bio Journal of North America. 2014;5(6):227-239.
5. Chiduza C. An agronomic evaluation of rationing in sorghum and competitive performance with maize and pearl millet in Northern Sebungwe, Zimbabwe. dphil Thesis. Department of Crop Science, University of Zimbabwe. 1993;310.
6. Madanzi T, Muhambi M, Manjeru P, Makeredza B, Darikwa TB. Effect of storage length on early stand establishment of four sorghum (*Sorghum bicolor* (L.) varieties in the smallholder sector of Zimbabwe. African Crop Science Conference Proceedings. 2007;(8):9-13.
7. Halmer T, Bewley JD. Physiological perspective on seed vigor testing. Seed Science and Technology. 1984;(12):516-575.
8. Harris D. Staying in control of rainfed crops. In: Proceedings of the first Annual Scientific Conference of the SADC/ODA Land and Water Management Programme October 8-10,1990. Gaborone, Botswana. 1992; 52-7.
9. Yamakawa H, Hirose T, Kunoda M, Yamaguchi T. Comprehensive expression profiling of rice grain filling related genes under high temperature using DNA micro array. Plant Physiol. 2007;(144):258-277.
10. Craufurd PQ, Wheeler TR. Climate change and the flowering time of annual crops. J Exp Bot. 2009;60(9):2529-2539.
11. ISTA. International Rules for Seed testing. International Seed Testing Association, Bassersdorf, Switzerland; 2005.
12. Hampton JG, TeKrony DM. Handbook of vigor test methods, (3rd edition). International Seed Testing Association (ISTA). Zurich, Switzerland; 1995.
13. Chiduza C, Waddington SR, Rukuni M. Evaluation of sorghum technology for

smallholder in semi-arid region of Zimbabwe (part one). Production practices and development of an experimental Agenda. J Appl Sci South Af. 1995;1(1):1-10.
14. Pereja MR, Staniforth DW. Seed soil characteristics in relation to weed seed germination. Weed Scie. 1985;33:190-195.
15. Prasad PVV, Boote KJ, Allen LH Jr. Adverse high temperature effects on pollen viability, seed set, seed yield and harvest index of grain sorghum (*Sorghum bicolor* (L.) Moench) are more severe at elevated carbon dioxide due to higher tissue temperatures. Agric For Meteorol. 2006;139:237-251.
DOI: 10.1016/;agrformet,2006.07.003.
16. Prasad PVV, Pisipat SR, Mutava RN, Tuinstra MR. Sensitivity of grain sorghum to high temperature stress during reproduction development. Crop Sci. 2008; 48:1911-1917.
DOI: 10.2135/cropsci,2008.01.0036.
17. Krishnan P, Surya Rao AV. Effects of genotype and environment on seed yield and quality of rice. 2005;143(4):283-292.
18. Harris D. The effects of manure, genotype, seedlings, seed priming, depth and date of sowing on emergence and early growth of sorghum in semi-arid Botswana. Soil Tillage Research. 1996;40:73-88.
19. Napo EN. Effects of watering interval, planting depth and soil crusting on emergence and seedling establishment of sorghum (*Sorghum bicolor* (L.) Moench). MSc thesis, University of Zambia; 2000.
20. Mohammad RA. Effects of planting depth on germination and the emergence of field Bindweed (*Convolvulus arvensis* L.). Asian J Agric Sci. 2011;3(6):459-461.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/15322