

Research Application Summary

Report on the implementation of the RUFORUM Post-Doctoral Fellowship: Enhancing crop productivity and household food security among smallholder farmers in Zimbabwe

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Abstract

Eliminating hunger and food insecurity is top on Africa's development Agenda because it is perceived to be a key factor in promoting economic growth. Africa continues to experience food shortages due to a mismatch between crop productivity and population growth. Reduced crop productivity is attributed partly to weed interference related crop losses and climate change and variability. This calls for more understanding of pertinent issues that affect crop production through multidisciplinary research in order to combat food insecurity challenges. To contribute to this effort, a Post-Doctoral Research Fellow, who in the past worked on a related topic, is working with a mentor and other senior researchers at the University of Zimbabwe as well as a team of graduate students to address some of the related research issues. Specifically, the Post-Doctoral Fellowship sought to 1) to promote resilient seed systems for adaptation to climate change by smallholder farmers in semi-arid agroecological regions of Zimbabwe, ii) to evaluate the agronomic potential of currently underutilised crops under harsh conditions of climate change and parasitic weeds, and to evaluate the antifungal effect of botanical extracts against late blight of tomato (*Phytophthora infestans*). The Post-Doctoral Fellowship has led to a series of lesson learning and experiences that are summarized in this paper. Research activities conducted during the Post-Doctoral training led to the identification of small grain genotypes that are resilient to witchweeds. The study also revealed the nutritional benefits and recommended agronomic practices for the production of an indigenous underutilised crop called Livingstone potato (*Plectranthus esculentus*). A new environmentally friendly and economically feasible innovative strategy of managing late blight of tomato using botanical extracts was developed.

Key words: Climate change, food Security, nutrient use efficiencies, parasitic weeds resilient Seed systems

Résumé

L'éradication de la faim et de l'insécurité alimentaire figure en tête du programme de développement de l'Afrique, car elle est perçue comme un facteur clé de la promotion de la croissance économique. L'Afrique continue de connaître des pénuries alimentaires en raison d'une inadéquation entre la productivité des cultures et la croissance démographique. La réduction de la productivité des cultures est attribuée en partie aux pertes de récoltes liées aux mauvaises herbes ainsi qu'au changement et à la variabilité climatiques. Il est donc nécessaire de mieux comprendre les questions pertinentes qui affectent la production agricole par le biais de la recherche multidisciplinaire afin de lutter contre les problèmes d'insécurité alimentaire. Pour contribuer à cet effort, un chercheur post-doctoral, qui a travaillé par le passé sur un sujet connexe, travaille avec un mentor et d'autres chercheurs chevronnés de l'Université du Zimbabwe ainsi qu'avec une équipe d'étudiants pour aborder

certaines des questions de recherche connexes. Plus précisément, la bourse post-doctorale visait à 1) promouvoir des systèmes résilients de semences pour l'adaptation au changement climatique par les petits exploitants agricoles dans les régions agroécologiques semi-arides du Zimbabwe, ii) évaluer le potentiel agronomique des cultures actuellement sous-utilisées dans des conditions difficiles de changement climatique et de mauvaises herbes parasites, et évaluer l'effet antifongique des extraits de plantes contre le mildiou de la tomate (*Phytophthora infestans*). La bourse post-doctorale a permis de tirer une série de leçons et d'expériences qui sont résumés dans ce document. Les activités de recherche menées au cours de la formation post-doctorale ont permis d'identifier des génotypes de petites céréales qui résistent aux mauvaises herbes. L'étude a également révélé les avantages nutritionnels de la pomme de terre Livingstone (*Plectranthus esculentus*), une culture indigène sous-utilisée, ainsi que les pratiques agronomiques recommandées pour sa production. Une nouvelle stratégie innovante de gestion du mildiou de la tomate, respectueuse de l'environnement et économiquement réalisable, utilisant des extraits botaniques, a été développée.

Mots clés : Changement climatique, sécurité alimentaire, efficacité de l'utilisation des nutriments, mauvaises herbes parasites, systèmes de semences résilients.

Introduction

The African continent has prioritized food security and nutrition as its first sustainable development goal (Vilakazi and Hendriks, 2019). Many African governments have put in place strategies to address this very important strategic goal which is key to promoting economic development and the wellbeing of the people of Africa. Reports show that there has been a steady increase in production and access to food in previously food insecure communities. However, the gains that have been reported in the recent past are being eroded by low crop productivity that is caused by climate change (Kassie *et al.*, 2013). The impacts of climate change include shortened growing seasons, increased incidence of difficult to control pests which adversely impact on the health of economically marginalized communities and are proving to be a real threat to food security. In Africa, the effects of climate change are more pronounced in the smallholder agricultural sector which is dominated by resource constrained farmers (Anderson *et al.*, 2010; Otto *et al.*, 2015). The problem is exacerbated by the fact that smallholder farmers continue to grow crops like maize (*Zea mays* L.) that are susceptible to the debilitating effects of climate change. Moreover, farmers continue to practice bad agronomic practices like monoculture that result in a buildup of parasitic witchweeds (Rugare *et al.*, 2013; Chitagu *et al.*, 2014). It has been reported that parasitic weeds can cause 20-80% yield loss depending on the susceptibility of the host (Mandumbu *et al.*, 2017). The decline in crop productivity has renewed the interest in promoting the production of underutilized cereals and neglected indigenous crops with resilience to the adverse effects of biotic and abiotic factors.

Horticultural crops like tomato (*Solanum esculentum*) play a significant role in ensuring household food security in many parts of sub-Saharan Africa (Oerke *et al.*, 2012), due to their richness in nutrients and role in small-scale trade (Cetin and Vardar, 2008). Tomato production in the resource limited communities is an important source of income specially in areas where farmers have limited access to land for production of cereals that require large portions of land (Zekeya *et al.*, 2017).

Emerging reports have shown a reduction in tomato production due to late blight (*Phytophthora infestans*) infection. This reduction has been attributed to lack of effective disease control strategies because *P. infestans* has developed resistance to some of the commonly used synthetic fungicides (Muthomi *et al.*, 2017). This has necessitated the development of alternative methods of disease control that are effective and environmentally friendly (Ngadze *et al.*, 2014). One such method is the exploitation of botanical extracts in integrated disease management of horticultural crops. This

study sought to identify botanical extracts that can be used by farmers to manage late blight of tomato. An interdisciplinary Post-Doctoral team was set up to carry out demand driven research in order to address some of the key production constraints affecting food security in vulnerable communities. The specific objectives of the Post-Doctoral Fellowship included (a) Strengthening interdisciplinary skills of the Post-doctoral research Fellow, (b) Strengthening leadership and mentorship skills of the Post doc Fellow, and (c) Enhancing household food security through provision of appropriate agronomic technologies.

Methodology and design of the study

The Post-Doctoral fellowship which was hosted by the University of Zimbabwe commenced in 2018. A multidisciplinary team comprising of a mentor, several academic supervisors from the University of Zimbabwe, a team of eight postgraduate and undergraduate students was set up. The Post-Doctoral team's research objectives were aligned with the strategic objectives of two research groups in the Department of Crop Science. Several field, glasshouse and laboratory studies were carried out as outlined later. Mentoring strategies used included (i) monthly laboratory meetings for the team where students would share experiences and report on progress in the presence of mentors, (ii) one on one meetings with the mentor/supervisor, and (iii) journal club where students would review published articles as a strategy of developing scientific writings skills of the Post-Doc and students. The Post-Doc fellowship also sought to develop presentation skills of members through participation at national scientific conferences. This initiative created a good working relationship among student in the team which saw them drafting manuscripts together and peer reviewing them before they were finally submitted for publication.

Emerging lessons

1. The multidisciplinary approach to Post-Doctoral training initiated by the RUFORUM Secretariat provided a platform where senior academic staff and students at different levels shared experiences that resulted in strengthening research, teaching and professional development. The multidisciplinary team that was set up by the Post-Doctoral Fellow promoted collaborative research among members of the team as evidenced by the team's ability to co-publish articles. Since scientific publications are an important measure of the Post-Doc for a faculty position or promotion, the number of papers published were increased through co-publishing articles in more than one discipline. The involvement of several students in a coordinated team provided an opportunity for students at different levels to co-publish which increases their competitiveness when applying for competitive grants/scholarships. The team approach motivated MSc and BSc students to participate at scientific conferences and subsequently publish their research, even though publishing was not mandatory for them.
2. The Post-Doc Fellowship team comprised of supervisors with divergent expertise in the field of Crop Science. The multidisciplinary approach provided a platform for the Post-Doc Fellow and students in the team to learn from more than one mentor. This cross fertilization of skills and knowledge led to the development of multi-skilled graduate students. Moreover, it broadened the Post-Doc's collaborative network since the students in the team had the opportunity to interact with seasoned researchers who work together with the senior researchers in the team.
3. This initiative fitted very well in the University of Zimbabwe's new programmatic approach to research and teaching since students who were part of the Post-Doctoral team were part of the Department of Crop Science's two research groups that are working on development of biopesticides and spearheading widespread adoption of resilient underutilized grains and indigenous plants. The programmatic approach proved to be very important in ensuring sustainability of research initiatives after termination of the Post-Doctoral Fellowship. Sustainability is achieved in two ways (i) it increases chances of the research groups to secure additional funding when an application which seeks to promote a multidisciplinary approach to training is made, and (ii) the team approach increases the longevity of research projects when

one or two members of the team leave which is key in ensuring that research teams carry out research until a new innovation is developed and commercialized.

4. The team approach enables students in the mentorship programme to enroll for higher degrees since they would have developed a working relationship with their supervisors/mentors. In this case one of the BSc students was immediately enrolled for the MSc degree under the supervision of supervisors in the team with the aim of assisting him to continue with the research that he did at undergraduate level. Similarly, MSc students in the Post-Doctoral team are being assisted to enroll for DPhil studies.
5. The programme created a platform for the Post-Doc and students in the team to participate in resource mobilization initiatives like grant application. The ability of student to solicit for research funds is key when developing future researchers and leaders in higher education. The Post-Doc Fellow and some of the students in the team participated in grant application. The team approach is key in this case because it enables the young researchers to leverage on the experience and networks of their mentors.

Progress made during the period 01 March 2018 - 31 August 2019

Student one: Isaac Chabata (DPhil), Discipline: Agronomy. Title of study: Fostering resilience to climate change improved seed production practices and crop diversity as a sustainable livelihood strategy in smallholder farming communities in Zimbabwe

The main objective is to promote resilient seed systems for adaptation to climate change by smallholder farmers in semi-arid agroecological regions of Zimbabwe. Specific objectives of the study include to 1) determine farm-retained seed varieties' tolerance to moisture and temperature variations using hydrothermal testing at germination and indigenous farmer knowledge, 2) identify and determine the most tolerant varieties and their future adaptability to moisture and temperature extremes using software tools and modelling software, and 3) to determine the resilience of local and introduced varieties to current moisture and temperature regimes in Mutoko District. Achievements: A survey was conducted which aimed at assessing the vulnerability of smallholder farmers to the effects of climate change in the cropping systems and a paper is being developed to that effect. A review paper has also been written and is being reviewed for publication. Local seed varieties have been collected from the farmers and their tolerance to moisture and temperature stress is to be determined using hydrothermal at germination. A poster presentation was done during the Research week at the University of Zimbabwe in August 2019.



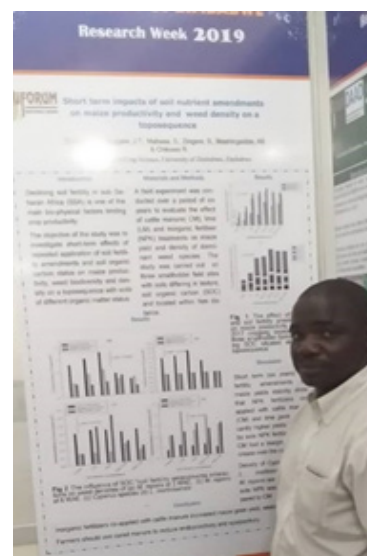
Student two: Gaudencia Kujeke (DPhil), Discipline: Agronomy

Title of study: Livingstone potato (*Plectranthus esculentus* N.E. Br) genetic diversity, agronomic, nutritional and post-harvest evaluation in Zimbabwe. The D.Phil. student conducted studies on Livingstone potato, an underutilized and neglected crop species in Zimbabwe. The research involved determining the best agronomic practices (fertilizer use, plant densities, seed size and planting depth and seed storage methods) and improving the planting material through tissue culture techniques. The study also looked at the genetic diversity of Livingstone potato lines from Malawi and Zimbabwe using morphological and molecular markers. The research addressed issues of nutritional benefits as well as value addition in a bid to improve awareness and adoption of the crop mainly among smallholder communities. Food products made from processed Livingstone

potato have been showcased at local food fairs and agricultural shows. The student published one article in the African Crop Science Journal and submitted a third article to the Advances in Agriculture Journal (Hindawi) where it is under review.

Student three: Justin Chipomho (DPhil), Discipline, Weed Science

Title of study: Soil fertility spatial variability-weed interactions and nutrient use efficiencies under smallholder farming system in Zimbabwe. The student carried out a survey and conducted several experiments under controlled and field conditions in a bid to (a) evaluate the influence of farmer practices/management and catena position on weed species dynamics and maize productivity, (b) evaluate the interactive effects of macro (N, P and K) and micro (Zn, B) nutrients on weeds and maize productivity, (c) investigate the relationship between nutrient management regimes, weed species dynamics, weed seed bank and maize yields, and (d) determine the effect of delayed weeding on maize yield in carbon rich/fertile soils. Field work was completed and the student has started writing the thesis. The student submitted two abstracts for poster and paper presentation that were published in the University of Zimbabwe's book of abstracts for poster and paper presentation during the University's biennial Research Week in July 2019. One article was submitted to the Heliyon Elsevier Open Access Journal and is currently under review. The student is currently developing a second manuscript.



Student four: Tedious Choga (MSc), Discipline: Plant pathology

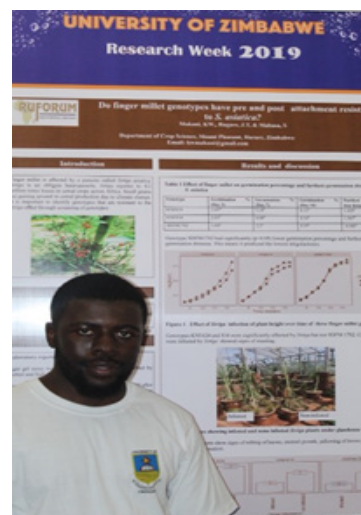
Title of thesis: In vitro and in vivo evaluation of antifungal activity of botanical extracts in the control of late blight (*Phytophthora infestans*) of tomato (*Solanum esculentum*). The student evaluated the efficacy of botanical extracts of *Eucalyptus nigra*, *Lantana camara*, *Azadirachta indica* and *Moringa oleifera* on late blight development on tomato. Laboratory and glasshouse experiments were carried out at the University of Zimbabwe. The laboratory experiments sought to establish the effect of different botanical extracts on radial growth, percent inhibition of *P. infestans* and response of defense enzymes in plants that were treated with different botanical extracts. In addition, greenhouse pot studies were carried out to evaluate the effectiveness of botanical extracts to control late blight disease on tomato plants. Results collected in all the experiments showed that botanical extracts of *A. indica* reduced disease development on tomato plants by 90% compared to the untreated control and consequently resulted in higher yields and better fruit quality. Gas Chromatography Mass Spectrometry revealed the presence of several compounds whose antifungal activity has previously been reported in literature. Overall, the study demonstrated the potential of incorporating botanical extracts as a cost effective and environmentally benign method of managing late blight of tomatoes. The student presented a Poster and live exhibits during the University of Zimbabwe Research Week and the Zimbabwe Agricultural show in August 2019. A newspaper article titled "UZ research team develops smart fungicide alternative for tomato plants" was published in the Business Connect of 19 August 2019. In addition, a summary of the findings from this study was included in the



Vice Chancellor graduation speech that will be read to the Head of State at the congregation of the University of Zimbabwe's 2019 graduation ceremony. The student is currently developing a manuscript for submission to an International Journal

Student five: Kudzai Makani (MSc), Discipline, Weed Science

Title of study: Screening finger millet (*Eleusine coracana* L. Gaertn) genotypes for resistance to witchweed (*Striga asiatica* L. Kuntze) infection. The student evaluated the response of three finger millet genotypes for tolerance to *S. asiatica* which is the major biotic factor limiting productivity of cereals in Zimbabwe's smallholder areas. The study was part of a bigger programme being undertaken by the Crop Protection research group at the University of Zimbabwe to select and promote widespread adoption of small grains with resilience to climate change and the debilitating effects of parasitic weeds in Zimbabwe's smallholder farming sector. The study identified a tolerant finger millet genotype (SDFM1702) whose performance in *Striga* endemic areas is going to be further evaluated in different field environments in the 2019/2020 season. The student presented a poster at the University of Zimbabwe's Biennial Research Week and the abstract was published in the book of abstracts. The poster was also showcased at the 2019 edition of Zimbabwe Agricultural show. A manuscript was developed and submitted to the African Journal of Rural Development

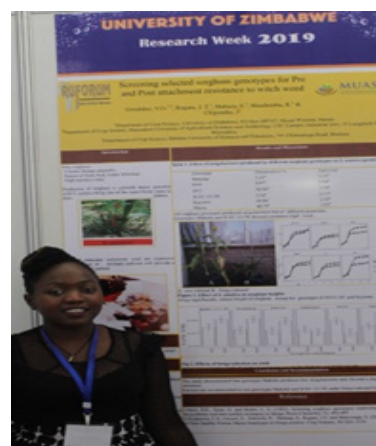


Student six: Rachel Moyo (MSc), Discipline: Weed Science

Title of study: Reaction of selected pearl millet (*Pennisetum glaucum* L.R. Br) genotypes to witchweed (*Striga asiatica* L. Kuntze) infection. This study sought to facilitate the widespread adoption of Africa's future grains which are currently neglected due to the overdominance of maize in the smallholder sector. The need to identify pearl millet genotypes that can withstand witchweed infection in the face of climate change is a key strategy in combating hunger due to low crop productivity. The study revealed the presence of two potentially resistant genotypes. The two genotypes are going to be included in a series of field trials that are going to be conducted in the 2019/2020 season to confirm the resistance of these genotypes under field conditions before they can be recommended to farmers in witchweed endemic areas. The student presented a poster at the University of Zimbabwe's Research Week and the Abstract was published in the book of Abstracts. The poster was also presented at the Zimbabwe Agriculture Show in August 2019. A research paper is being prepared for publication in a suitable International Journal.

Student 7: Varaidzo Gwatidzo (MSc), Discipline: Weed Science

Title of study: Screening selected Sorghum (*Sorghum bicolor* Moench) genotypes for resistance to witchweed (*Striga asiatica* L. Kuntze) infection. The study screened seven drought tolerant sorghum genotypes for resistance to witchweed. The study aimed to identify sorghum genotypes that can be recommended for farmers in areas where maize production is no longer sustainable due to the simultaneous devastating effects of drought and witchweed infestation. The study which was carried out under laboratory and pot conditions showed that the genotype Mahube had pre-attachment resistance to *S. asiatica* infection whereas the genotypes SV4 and ICSV111 IN exhibited tolerance and could be evaluated under field conditions in different agroecological regions before final



recommendations are made. Achievements: The results from this study were published in the University of Zimbabwe's book of abstracts and a poster was presented at the Research Week as well as the Zimbabwe Agricultural Show in August 2019. The student is currently developing a manuscript for submission to an International Journal.

Student eight: William Makaza (BSc), Discipline: Weed Science

Title of study: Response of groundnut (*Acharris hypogea* L.) genotypes to yellow witchweed (*Alectra vogelii* Benth.) infestations. Groundnut is commonly grown in the smallholder sector in rotation with cereals like maize, finger millet, pearl millet and sorghum. Alternatively, it can be intercropped with cereals. The production of groundnut is affected by an important parasitic weed of legumes called *A. vogelii*. A study was done to select groundnut genotypes that can resist or withstand the debilitating effects of *A. vogelii*. Results obtained in this study identified one genotype with complete resistance to witchweed infection and two genotypes with tolerance to yellow witch weed infection. The resistant and tolerant genotypes identified in the study will be evaluated in multilocational intercropping and crop rotation trials in the 2019/2020 rain season. Results from this study were presented during the Research Week at the University of Zimbabwe and this created an opportunity for collaboration with a local seed company. The student also presented a poster and the abstract of the paper was published in the book of abstracts. In addition, a poster was presented at the Zimbabwe Agricultural Show. A research paper was submitted to the African Journal of Rural Development.

Publications with students in the Post Doc Fellow's team

- Kujeke, G.T., Mazarura, U., Ngadze, E., Gasura, E., Rugare, J.T., Matikiti, A. and Masekesa, R.T. 2019. Untapped potential of livingstone potato, an indigenous and underutilised root crop in Zimbabwe: A review. *African Crop Science Journal* 27 (2): 307 — 320.
- Rugare, J.T., Pieterse, P.J. and Mabasa, S. 2019. Effect of short-term maize-cover crop rotations on weed emergence, biomass and species composition under conservation agriculture. *South African Journal of Plant and Soil* (In Press).
- Rugare J.T., Pieterse P.J. and Mabasa, S. 2018. Biochemical and morphological roles of allelopathic crops in integrated weed management: A review. *African Journal of rural and Development* 3 (3): 869-882.

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- Chaniwa, M., Nyawenze, C., Mandumbu, R., Mutsiveri., G., Gadzirayi, C.T., Munyati, V.T. and Rugare, J. 2020. Ending poverty through affordable credit to small scale cotton farmers: The case of the Cotton Company of Zimbabwe. In: Nhamo, G., Odularu, G. and Mjimba, V. (Eds.), *Scaling up SDGs Implementation*. Springer International Publishing PG, Cham. In press. (Book chapter).
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Manuscripts Submitted for publication

- Kujeke, G., Chitendera, T.C., Masekesa, R.T., Ngadze, E., Mazarura, U., Rugare, J.T. and Matikiti, A. Micropropagation of Livingstone potato (*Plectranthus esculentus* N.E.Br). *Advances in Agriculture* (Under review)
- Chipomho, J., Rugare, J.T. Mabasa, S., Zingore, S. Mashingaidze, A. 13. and Chikowo, R. Short-term impacts of soil nutrient management on maize (*Zea mays* L.) productivity and weed dynamics on a toposequence. *Heliyon* (Under review)
- Kwashie, F.N., Rugare, J.T., Mabasa, S., Gasura, E. and Mandumbu, R. Selecting for improved productivity in open pollinated maize (*Zea mays* L.) under *Striga-infested* and *Striga-free* environments. *International Journal of Agronomy* (working on received peer reviews).
- Murimwa, J. C., Rugare, J. T., Mabasa, S. and Mandumbu, R. Effects of sorghum (*Sorghum bicolor*) aqueous extracts and mulches on beggarticks (*Bidens pilosa*), Goose grass (*Elzaine indica*) and sesame (*Sesamum indicum*). *Agricultural Research* (Springer)— (Working on received peer ws).
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- Makaza, W., Rugare, J. T., Mabasa, S., Gasura, E., Gwatidzo, O.V. Makani, K.W. and Mayo, R. Response of groundnut (*Arachis hypogea* L.) genotypes to yellow wit hweed (*Alectra vogelii* Benth.) infestation. *African Journal of Rural Development*. (In Press)

Papers/Posters presented at conferences

- Chipomho J., Rugare, J.T., Mabasa, S., Zingore, S., Mashingaidze, A.B. and Chikowo, R. 2019. Short term impacts of soil nutrient amendments on maize productivity and weed physiognomies under smallholder farming system. Poster presented at the University of Zimbabwe Research week, 5-10 August 2019, Harare, Zimbabwe. Abstract published in Book of Abstracts Research Week 2019, page 180.
- Chipomho J., Rugare, J.T., Mabasa, S., Zingore, S., Mashingaidze, A.B. and Chikowo, R. 2019. Productivity and weed community response to fertilizers across soil fertility domains in smallholder farms of Hwedza. Abstract published in Book of Abstracts Research Week 2019, page 182.
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- Moyo, R.K., Rugare, J.T., Chipomho, J., Mandumbu, R., Mabasa, S., Mubasa, S. and Makani, K.W. Screening of pearl millet genotypes (*Pennisetum glaucum*) genotypes for tolerance/resistance to

- witchweed (*Striga asiatica*). Poster presented at the University of Zimbabwe Research week, 5-10 August 2019, Harare, Zimbabwe. Abstract published in Book of Abstracts Research Week 2019, page 201.
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- Murimwa, J.C. Rugare, J.T., Mabasa, S. and Mandumbu R. 2019. A I lelopathic effect of sorghum (*Sorghum bicolor* L. Moench) extracts on sesame (*Sesamum indica* L.) varieties and selected weeds. Poster presented at the University of Zimbabwe Research week, 5-10 August 2019, Harare, Zimbabwe. Abstract published in Book of Abstracts Research Week 2019, page 203.
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- Rugare, J.T., Pieterse, P.J. and Mabasa, S. 2018. Evaluation of the potential of *Canavalia ensiformis* aqueous extracts as post emergence bio-herbicides for weed control in maize (*Zea mays* L.). Paper presented at the Sixth African Higher Education Week and RUFORUM Biennial Conference October 2018, Nairobi, Kenya.
- Rugare, J.T., Mukomberanwa, K. and Mabasa, S. 2018. Impact of agronomic practices and soil type on weed dynamics in Hwedza communal area of Zimbabwe. Poster presented at the Sixth African Higher Education Week and RUFORUM Biennial Conference October 2018, Nairobi, Kenya.

Conclusion

The multidisciplinary post-doctoral training proved to be a good strategy for expanding research skills, develop independence and shape career trajectories as this was done in the context of career development. The multidisciplinary approach to post-doctoral training afforded the members in the team to appreciate the importance of conducting multidisciplinary research in order to solve problems since challenges that farmers encounter require expertise from different disciplines. In this case, involvement of weed scientists, plant pathologists, agronomists and plant breeders enabled the Post-Doctoral Fellow and students to appreciate different technics of conducting demand driven research.

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