Effect of Placement Depth of Planting Fertilizer on Above and Below Ground Growth Characteristics of Centrosema pubescens

Joel, D. A. and Mtengeti E. J.

Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture, P. O. Box 3004, Morogoro, Tanzania. ***Corespondence***: *doricejoel20@gmail.com*

Abstract

Livestock production in Tanzania is limited by poor availability of high nutritional forage species from natural grazing land. The leguminous fodder seems to be the best options for livestock feeding due to their high nutritive values especially protein contents, but their productivity is limited by unpredictable rainfall and poor soil fertility particularly in semi-arid regions. Although application of phosphate fertilizers is recommended for increasing productivity of Centrosema pubescens, yet poor agronomic practices especially the optimal fertilizer placement depth constraints its growth performance during establishment. This study tested the influence of Diammonium phosphate (DAP) fertilizer placement depth on above and below ground growth characteristics of Centrosema pubescens during establishment at Magadu Dairy Farm located at Sokoine University of Agriculture. The five fertilizer placement depths i.e. 0 cm, 5 cm, 10 cm, 15 cm, and 20 cm, were compared in terms of growth characteristics of both roots and shoots as well as above ground biomass yield. It *was found that the above ground biomass production, shoots growth and root growth characteristics increases with increasing levels of planting placement depth. The optimal depth recommended for maximum yield was at 15 cm. It was suggested that farmers should adhere to recommended fertilizer placement depth for good establishment of Centrosema pubescens.*

***Keywords**: Fertilizer, placement depth, above ground biomass, and growth characteristics.*

Introduction

Availability and quality of forage in arid and semi-arid regions is the main constraints for livestock production. High seasonal fluctuation in forage productivity in Tanzania is associated with unpredictable rainfall. Most natural grasses have low nutritional values because they are characterized by rapid maturing which accompanied by decline in protein content and lower digestibility (Mwilawa *et al*., 2008). Establishment of high yielding legume fodders such as *Centrosema pubescens* have been recommended particularly in high populated areas with scarcity of natural pasture (Mtengeti *et al.*, 2008). Despite high demand for leguminous fodder, there is low production of *Centrosema pubescens* in Tanzania. Low productivity of *Centrosema pubescens* is associated with among other things, the poor agronomic skills particularly application fertilizer. Although there are different techniques of fertilizer placement there is still scant information on the appropriate depth which farmers could use in establishing the legume. The information on fertilizer placement depth on optimal growth rate is very crucial for sustainable leguminous fodder production.

Some efforts have been initiated to overcome the shortage of forage in Tanzania, such as establishment of improved legumes fodders through reseeding and application of fertilizers. Nevertheless, the maximum production has not been achieved due to lack of agronomic skills. Understanding the correct amount of fertilizer required and the appropriate placement depth is one step toward improving quality and productivity of leguminous fodder. Many farmers are facing challenges regarding to the best way on how to apply fertilizer in order to increase pasture productivity.

Magadu Farm is one of the production units in Sokoine University of Agriculture (SUA) under the Department of Animal, Aquaculture and Range Sciences dealing with livestock and fish production. Pasture production in this farm is facing several challenges including persistence drought due to unreliable rainfall, poor soil fertility and lack of high yielding pasture seeds. Although establishment of leguminous fodder is recommended because of their high nutritional value and ability to fix Nitrogen, but in very low soil fertility, application of fertilizers rich in phosphate especially during sowing period is imperative. The challenge here is at what depth the fertilizer should be placed in order to offer maximum nutrient utilization and subsequent root growth. Therefore, this study investigated the appropriate fertilizer placement depth for optimal growth performance and above ground biomass yield for *Centrosema pubescens.*

Material and Methods

Description of study area

On-station experiment was carried out at Magadu Dairy Farm of Sokoine University of Agriculture (SUA), which is situated about 5 km south west of Morogoro town. Selection of Magadu farm as study area was based on easy accessibility for monitoring the study plots in daily basis. The area receives bimodal rainfall pattern ranging from 800 to 900 mm per annum (Kizima *et al.*, 2014). Short rains normally starts from early November up to the end of December while the long rains start in early March up to the end of May or early June of each year. The relative humidity (RH) of the area is 81% during rainy season with the daily temperature ranging from 25ºc to 30ºc (Kizima *et al.*, 2014). The study area is characterized by wooded bush land dominated with Acacia species. The most prevalence Acacia species in this area is *A. nilotica*. Among the desirable grass species dominating the study area includes; *Urochloa*, *Borthrochloa, Cynodon* species and *Hyparrheni*a species while undesirable grass species are *Sporobolus pyremidalis*. Among the undesirable forbs found in the study area are *Solanum incunum* and *Lantana camara*. The study area also contains some legumes species such as *Centrosema pubescens*, *Calopogonium mucunoides, Clitoria ternatea, Neonotonia wightii and Macroptilium* species. Generally plant cover within the area is relatively good with minimum bare land and little signs of soil erosion. The soil structure of the area ranges from sandy loam to sandy clay (Kizima *et al.*, 2014).

Experimental design

The experiment was carried out at the pasture museum in Magadu Dairy Farm. Five different placement depth (0, 5, 10 15, and 20 cm deep) were considered as different levels of treatments. These levels were replicated four times using the transparent plastic bags as planting pots. In each planting pot, the same type and amount of soil collected from the farm was used as planting media. All treatment levels received the same agronomic practices such as sowing rate, weeding, pest and disease control as well as same amount of Diammonium phosphate fertilizer. Each pot received 5 g Diammonium phosphate mixed with 10 kg soil during sowing stage. The ratio of Phosphate to Nitrogen contained in the applied DAP was 2.5: 1 respectively.

Data collection

Data collection commenced on week 2 after planting. Data were collected weekly for total of 13 weeks consecutively. Growth performance was determined by measuring the height of plants and counting the number of leaves and branches every week for duration of 13 weeks. Root growth was also determined by measuring the length of roots and counting the nodules. The above and below ground biomass was determined by using destructive method through harvesting samples drying and weighing. Samples were taken to the laboratory of department of Animal, Aquaculture and Range Science for determination of dry matter. Samples were oven dried for 24 hours under 70^{o}C.

Data analysis

Collected data were subjected to General Linear model using SAS of 2004. The effect of different fertilizer placement depth on above and below ground growth characteristics of *Centrosema pubescens* was compared by using One-way Analysis of Variance (ANOVA). The following statistical model was used to analyze the data and the hypothesis was tested at 5% level of significance.

Bij= μ + Pi + eij.

Where; Bij = Yield of the effects of i^{th} fertilizer placement depth due to j^{th} factor

(DAP fertilizer)

μ = General mean effect.

Pi = Effect of i^{th} treatments levels of fertilizer placement depth.

eij = Random error.

Results and Discussion

The study revealed that, Diammonium phosphate was more effective in improving growth performance of *Centrosema pubescens.* Generally legumes show better response to phosphorous application because they obtain their Nitrogen requirement via symbiotic pathways (Benton, 2012). This was evidenced by higher growth performance in all pots received DAP compared to the control experiment. Nevertheless, all growth attributes (number of leaves, number of branches and the length of branches) were found to increase with increasing fertilizer placement depth. Results in Table 1, indicate that the optimal depth for highest growth of shoots was at 15 cm deep. Above 15 cm deep, there was decline in the number of leaves, number of branches as well as the mean length for branches. This is probably attributed by rooting behavior of most legumes that tend to penetrate the soil deep to certain level.

Table 1. The effect of different placement depth of planting (DAP) fertilizer on *Centrosema pubescens* above ground growth performance

Parameter	Fertilizer placement depth in cm/20 pots					SE	P-value
	0	5	10	15	20		
Number of leaves	107.71^{c}	191.87^{b}	254.23^{b}	338.60^{a}	232.44^{b}	28.015	0.0001
Number of branches	57.52^{b}	69.42^{b}	87.48^{ab}	114.31^{a}	81.98^{b}	10.014	0.0014
Length of branches (cm)	37.90^{b}	40.41^{b}	54.602^{b}	72.785^{a}	42.99^{b}	6.147	0.0003

Means with different superscript within rows are significantly different ($P < 0.05$)

Similar trend was observed in root growth characteristics (Table 2). The length of roots and number of nodules increased with increasing fertilizer placement depth.

However, in the context of roots, 20 cm deep was found to be the optimal level for highest root growth. For example the length of roots increased by 45 % at 20 cm placement depth compared 5 cm deep.

Table 2. The effect of different placement depth of planting (DAP) fertilizer on root growth characteristics of *Centrosema pubescens*

Parameters	Fertilizer placement depth in cm/20 pots					SE	P-Value
	0	5	10	15	20		
Length number of roots in cm	29.75^{e}	35.00^{d}	39.10^{c}	44.75^{b}	50.80^{a}	1.06	0.0001
Number of nodules	11.75^{e}	21.50^{d}	31.25^{c}	41.75^{b}	50.50^{a}	0.581	0.0001

Means with different superscript are significantly differences ($P < 0.05$)

Similarly, the number of nodules double at 20 cm placement depth compared to those at 5 cm placement depth. Since phosphorous is relatively immobile in the soil compared to Nitrate and Sulphate, it is therefore important to understanding the correct placement depth for maximum growth rate of legumes.

The above ground and below ground biomass yields for *Centrosema pubescens* found to increase with increasing placement depth for DAP. There was high correlation between growth performance and biomass production. The higher the placement depth, the more the yield. The above ground biomass increased by 39% at 15 cm placement depth compared to those found at 5 cm fertilizer placement depth. However, the below ground biomass increased by 23 % at 20 cm placement depth compare to 5 cm placement depth. Above 15 cm placement depth, both above and below ground biomass found to decline (Table 3). These findings are consistence with those of Lester *et al.,* (2016) who established positive yield of leguminous fodder with increasing phosphorous depth.

Table 3. The effect of different placement depth of planting (DAP) fertilizer on dry matter yield of *Centrosema pubescens*

Parameters	Fertilizer placement depth in cm/20 pots					SE	p-value
	0	5	10	15	20		
Leaves yield (g)/pot	19.58^{d}	21.62^{c}	25.46^{b}	30.10^{a}	24.39^{b}	0.393	0.0001
Root yield(g)/pot	19.66^{d}	20.68^{cd}	23.23^{b}	25.46^{a}	21.33^{c}	0.401	0.0001

Means with different superscript are significantly differences ($P < 0.05$)

Conclusion and recommendation

The results of present study indicate that addition of Diammonium phosphate fertilizer is an important element affecting both growth performance and biomass yield. Growth performance of *Centrosema pubescens* in terms of roots and shoots tend to increase exponentially with increasing fertilizer placement depth and the optimal levels were 15 and 20 cm deep respectively. Similarly, the current study established positive yield in terms of above ground and below ground biomass with increasing DAP placement depth up to 15 cm deep of which above this level the yield were found to decline. The study recommended that farmers should apply Diammonium phosphate fertilizer at correct placement depth for maximum productivity. In this context, the 15 cm level is recommended for *Centrosema pubescens.* However, further studies are recommended to validate the optimal levels for phosphorous placement depth in leguminous fodder production.

References

Benton, J. (2012). Inorganic chemical fertilizers and their properties. Plant Nutrition and Soil Fertility *Manual*, Second Edition, 157–168. doi:10.1201/b11577-25.

Kizima J B, Mtengeti E J and Nchimbi-Msolla S (2014). Seed yield and vegetation characteristics of *Cenchrus ciliaris* as influenced by fertilizer levels, row spacing, cutting height and season. *Livestock Research for Rural Development. Volume 26, Article #148.* Retrieved January 5, 2018, from http://www.lrrd.org/lrrd26/8/kizi26148.htm.

Lester, D. W., Bell M., Graham R. Sands D. and Brooke G. (2016). Phosphorus and potassium nutrition. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/phosphorus-and-potassium-nutrition.

Mtengeti E. J., Phiri, E. C. J. H Urio, N. A. Mhando, D. G. Mvena, Z. Ryoba, R. Mdegela, R. Singh, B. R. Mo, M. Wetlesen, A. Lørken T. & Reksen O. (2008). Forage availability and its quality in the dry season on smallholder dairy farms in Tanzania. *Acta Agriculturae Scandinavica, Section A – Animal Science*, 58:4, 196-204.

Mwilawa, A. J. Komwihangilo D. M. and Kusekwa M. L. (2008). Conservation of forage resources for increasing livestock production in traditional forage reserves in Tanzania. *African Journal of Ecology* 46 (Suppl. 1), 85–89.

Harnessing Plant Characterization for Sustainable Production of Livestock Forages under Environment Stress

Lutatenekwa D. L.

Department of Animal, Aquaculture and Range Sciences,Sokoine University of Agriculture, P.O.Box 3004, Morogoro, **Corespondence**: dorice.luta@suanet.ac.tz

Abstract

Optimizing the reliability and resource use for efficiency forage production is a requirementtofeed a growing world population amidst environmental stress. One way in achieving optimization is to characterize and refine plant genotype-by-environment-by-management interactions, for enhancing plant growth, abiotic stress tolerance and disease resistance.This review paper attempts to account how harnessing plant characterization assist foranadaptation to environmental stresses and thus improved animal feeds production. In the field of range management, plant characterization is a technique of describing plant germplasm; it simplifies grouping of accessions, development of core collections, identification of gaps and retrieval of valuable germplasm for breeding programmesresulting in better insight about the composition of the collection and its genetic diversity. Plant characterization by morphological, physiological and agronomic descriptors has long been used in selective breeding. Advancement of characterization to the use of molecular markers fast-track the process and permits *optimal utilization of the adaptation traits harboured in all breeds for stressful environments. In countries like Tanzania, where agro-climatic conditions are challenging, technological progress is slow and market institutions are poorly developed, selected traditional varieties with high adaptation ability to various environmental tresses are important. Accumulated knowledge on traditional varieties could be used to breed fast adaptive varieties, which would prove to be resilient to environmental stresses. In this paper, therefore, some important environmental stresses namely soil moisture deficit and soil salinity and plant characterization technique described are well reviewed.*

Keywords: *Plant characterization, animal feeds, environmental stresses*

Introduction

The demand for livestock products has escalated with growing human population and improvement of living standards.According to the United Nations report (2018) the world population is projected to be 8.3 billion by 2030, following an increase of 0.5 billion people in five years, that is from 7.2 billion in 2013 to about 7.7 billion in 2018 (UNPP, 2018). Scholars predict the demand for livestock products to almost double by 2050, mostly in the developing world owing to growingpopulation, urbanization and increased income (Herrero *et al.,* 2009; Thornton, 2010). Household consumption patterns depend on size and economic weights, so the growing human population and increased poverty reduction would raise the demand of livestock products (Thornton, 2010). Increased demand for livestock products goes parallel with increased demand of resources to produce livestock products.

Livestock producers mainly depend on natural pastures in rangelands for feed resources which are low in quality and quantity for sustainable animal production (Msalya *et al.*, 2017). Valuable pasture species are becoming rare and many have disappeared or on the brink of extinction (Al-Rowaily, 1999). Loss of diversity has consequences beyond just the extinction of species. Once local populations of plants or animals are wiped out, the genetic diversity contained ineach species that provide the capability to adjust to environmental changes is weakened.With exacerbated environmental stresses, serious threats that limit both plant and animal productivity becomes worse (Singh *et al.,* 2011).

Environmental stresses are classified as biotic and abiotic stresses. Biotic stresses include living disturbances like pest insects and animals and abiotic stress are of several forms but the prevalent ones are those with common effect on plant water status (Verslues*et al.*,2006). According to Verslues *et al.* (2006), decrease of water potential for a plant to perform its biological roles can be caused by drought, extreme low temperatures, and salinity. There are variability within plants of the same species and among different species in their way of responding to environmental stresses. Wild plants and animals extinctions, distributional and species' range shifts and apparently gradual biological changes are associated with responses to environmental stresses (Easterling *et al.*, 2000; FAO, 2007).This paper narrates the role of plant characterization to enhance sustainable animal feeds production under environmental stresses specifically, drought and soil salinity.

Environmental stresses affect the products and services provided by agricultural biodiversity which is not limited to crop production. The far reaching effects go to livestock and livestock products responding to the impacts on grasslands and rangeland productivity (Hoffmann, 2010).Hoffman noted that geographically restricted infrequent species are severely affected by environmental stresses. Indirect effects of these stresses may be feltthrough ecosystem changes that alter the distribution of animal diseases and/or affect the supply of feed (Chakraborty, 2000). In pastoral and agro pastoral communities, livestock is a vital asset for accomplishing multiple functions rangingfrom economic to social and risk management (Swanepoel *et al.*, 2010).

Drought and Livestock Feed Resources

Livestock production systems in developing countries are facing losses in response to a number of drivers (Thornton *et al.,* 2009). Among those are climate driven losses, including lengtheneddroughtsacross the world affecting forage and crop production (Nardone*et al.,* 2010). Drought has the potential to impact the quantity and reliability of forage production, quality of forage, water demand for cultivation of forage crops, as well as large-scale rangeland vegetation patterns (Giridhar and Samireddypalle, 2015).

Most of the production losses are experienced though indirect impacts of drought, basically through reductions or absence of feed and quality water resources (Sejian *et al.*, 2016). Unstable distribution of rainfall in growing season in several regions of the world, impact forage production on large extent.

The most significant direct impact of drought on livestock production comes from heat stress. Hot environment blights production in terms of growth, yield and quality of feed produced, resulting in a significant financial burden to livestock producers through decrease in milk production, meat production, reproductive efficiency and animal health (Nardone et al., 2010). According to Sejian *et al*., (2016) and Naqvi *et al.* (2015) an increase in temperature and humidity could directly affect animal performance by decreasing fertility caused by decreased expression of overt oestrus and reduction in appetite and dry matter intake. The deficiency of water affects animal physiological stable equilibrium leading to loss of body weight, low reproductive rates and a decreased resistance to diseases, De Rensis and Scaramuzzi, (2003). Emerging diseases that may arise as a result of drought result in severe economic losses (Chakraborty, 2000). Improving livestock systems through improvement of water management and improving the ability of animals to cope with drought stress have been tried (Nardone *et al.,* 2010). In addition to above mentioned efforts, plant improvement programmes targeting desirable traits for stress tolerance, high output and adaptive traits in the changing climate are to be of great concerned. The success of these programmes depend on availability and accessible characterized plant resources. With proper adaptation actions supported by plant selection and breeding of species with preferable characters, it is possible to lessen the adverse impacts of drought (Giridhar and Samireddypalle, 2015) and guarantee livestock productivity through optimum forage obtainability.

Salinity and Livestock Feed Resources

Salinity refers to the concentration of dissolved salts in soils and water which is usually expressed in parts per million (ppm) or by weight milli equivalent) or molar mass (mM) of a given salt. High concentrations of salt in soils result from irrigation using saline water also when evapotranspiration exceed precipitation (Nosetto *et al.,* 2008). Accumulated salt decreases the osmotic potential of the soil that plants cannot take up water from it, this is a major constraint in agricultural production. Some plant species are capable of growing under saline soil conditions. Masters *et al.,* (2007) reported that both legumes and grasses with moderate salt tolerance are capable of providing 5–10 t of edible dry matter (DM) year−1, at the lower levels of salinity (<15 dS m−1) particularly when the availability of water is high. Production levels drop and the plant options decrease significantly at high salt concentrations (>25 dS m−1). Although production drops at the mentioned salt concentration, halophytic grasses and shrubs are able to continue producing. The challenge is that high concentrations of soil and water salt lead to accumulation of minerals like sodium, magnesium, calcium and potassium in these plant at intolerable levels to the animals. It is denoted by Masters *et al.,* (2007) that high concentrations of salts cause depressed food intake and may impair animal health.

In order to have salinity tolerant plants, characterisation is inevitable. Acknowledging the importance of plant characterization, Iseki *et al.*, (2016) for example, evaluated 69 accessions of genus *vigna* clustering them into groups of more tolerant, tolerant, moderately susceptible and susceptible. Interestingly Iseki *et al.*, (2016) found six accessions to be more tolerant to high salt concentrations suggesting their potential to contribute improving the poor salt tolerance in legume crops through genetic mechanisms. More plant species used for livestock feeds, legumes and grasses need to be characterised to enhance selection and breeding of stress tolerant species.

Plant Characterization

Plant Characterization is referred to as an account of heritable characters varying from morphological, agronomical features to molecular markers (Hassen *et al.*, 2006). Molecular markers are prominently used for evolutionary studies,evaluating interrelationship among accessions and among geographical groups.They are also potential for estimation of genetic diversity and identification of duplicates. Bioversity International (2007) inferred that morphological or visible descriptors remain important for identifying landraces accession. Morphological descriptors will continue to be used especially in developing countries until molecular markers are easily accessible The process of plant characterization involve recording and compilation of data on the important characteristics which distinguish accessions within species, to enable an easy and quick discrimination among phenotypes (Bioversity International, 2007). It allows simple grouping of accessions, development of core collections, identification of gaps and retrieval of valuable germplasm for breeding programmes, resulting in better insight about the composition of the collection and its genetic diversity.

The Novel of Plant Characterization

With advancement of agricultural and allied science and technology, still the ability to feed the increasing number of both human and livestock in the next twenty years is uncertain, particularly because of the challenging environmental conditions. Various strategies to optimize the reliability and resource use for increased forage production have been proposed by scholars (Busby *et al.*, 2017). Plant Characterization is one of priority areas expected to contribute in ensuring adaptive and productive genes are identified and appropriately utilized to enhance plant productivity. Govindaraj *et al.* (2015) suggested that application of plant characterization will lead to long-lasting increased food productivity and benefit the environmental.It is explicitlythat plant characterization can lead to capturing of plant genetic diversity; store it in the form of plant genetic resources like the gene bank and DNA library for long period. The conserved plant genetic resource is readily available materials to be utilized for crop improvement in order to meet future global challenges in relation to food and nutritional security. The use of genetic resources is limited by inadequate essential information on phenotypic and genotypic characters (Shantharaja *et al.*,2015). Since plant breeding research and cultivar development are integral components of improving food production, therefore, availability of and access to information on diverse genetic sources will ensure that the global food production network becomes more sustainable (Govindaraj *et al.*,2015).

At the current state of knowledge, predictabilityof effects ofclimate changeon the rate of natural and artificial selection remain largely anecdotal. It was denoted in Hoffman (2010) thatmost tropically adapted varieties are essentially uncharacterized.Optimal utilization of the adaptation traits harboured in all breeds, research into genetic characterization and understanding of adaptation in stressful environments needs to be strengthened for the sustainable livestock forages production.

Conclusion

Evidence on substantial decline in livestock feedsquality and quantity due to environmental stresses calls for appropriate strategies to optimize reliability of forage production with scarce resources. More so today, taking advantages of available tools and technologies like plant characterization to improve plant selection and breeding targeting adaptable traits to environmental stresses. Plant characterization fast track the process of generating information on desirable plants traits. Systematic information generated will assist plant breeders to efficiently select adapted plants to environmental stresses;

thestrategy would increase the sustainability and productivity of forage and livestock.

References

Al-Rowaily, S. L. (1999). Rangeland of Saudi Arabia and the "Tragedy of Commons". *Rangelands Archives*, 21(3), 27-29.

Basse, C. W., Stumpferl, S., andKahmann, R. (1999). Characterization of a. *Ustilagomaydis*.

Bioversity International- IPGR(2007). Guidelines for the development of crop descriptor lists. *Bioversity Technical Bulletin Series.*Bioversity International, Rome, Italy.

Busby PE, Soman C, Wagner MR, Friesen ML, Kremer J, and Bennett A (2017) Research priorities for harnessing plant microbiomes in sustainable agriculture. *PLoSBiol 15(3): e2001793.* *https://doi.org/10.1371/journal.pbio.2001793*.

Chakraborty, S., Tiedemann, A. V., and Teng, P. S. (2000). Climate change: potential impact on plant diseases. *Environmental pollution*, *108*(3), 317-326.

De Rensis, F., &Scaramuzzi, R. J. (2003). Heat stress and seasonal effects on reproduction in the dairy cow—a review. *Theriogenology*, 60(6), 1139-1151.

Easterling, D. R., Meehl, G. A., Parmesan, C., Changnon, S. A., Karl, T. R., and Mearns, L. O. (2000). Climate extremes: Observations, modelling, and impacts. *Science*, 289(5487), 2068-2074.

Engels, J.M.M. and Visser, L. (eds) (2003). A guide to effective management of germplasm collections. IPGRI Handbooks for Genebanks No. 6. IPGRI, Rome, Italy.

FAO (2007). Adaptation to Climate Change in Agriculture, Forestry, and Fisheries: perspective, framework and priorities. *FAO, Rome*.

Giridhar K., Samireddypalle A. (2015) Impact of Climate Change on Forage Availability for Livestock. In: Sejian V., Gaughan J., Baumgard L., Prasad C. (eds) *Climate Change Impact on Livestock: Adaptation and Mitigation*. *Springer*, New Delhi.

Govindaraj, M., Vetriventhan, M., & Srinivasan, M. (2015). *Importance of Genetic Diversity Assessment in Crop Plants and Its Recent Advances*: An Overview of Its Analytical Perspectives. *Genetics Research International*, 2015, 431487.

Hassen, A., Rethman, N. F. G., and Apostolides, Z. (2006). Morphological and agronomic characterisation of Indigofera species using multivariate analysis. *Tropical Grasslands*, *40*(1).

Herrero, M., Thornton, P. K., Gerber, P., and Reid, R. S. (2009). Livestock, livelihoods and the environment: understanding the trade-offs. *Current Opinion in Environmental Sustainability*, *1*(2), 111-120.

Hoffmann, I. (2010). Climate change and the characterization, breeding and conservation of animal genetic resources. *Animal genetics*, 41(s1), 32-46.

Iseki, K., Takahashi, Y., Muto, C., Naito, K., andTomooka, N. (2016). Diversity and Evolution of Salt Tolerance in the Genus Vigna. *PloS one11(10): e0164711.doi:10.1371/journal.pone.0164711*.

Naqvi, S. M. K., Kumar, D., Kalyan, De, Sejian, V. (2015). Climate change and water availability for livestock: impact on both quality and quantity. In: *Climate change Impact on livestock: adaptation and mitigation*(Sejian, V., Gaughan, J., Baumgard, L., Prasad, C. S. Eds), Springer-VerlagGMbH Publisher, New Delhi, India, pp 81-96.

Masters, D. G., Benes, S. E., and Norman, H. C. (2007). Biosaline agriculture for forage and livestock production. *Agriculture, Ecosystems & Environment*, 119(3-4), 234-248.

Msalya, G., Lutatenekwa, D., andChenyambuga, S. W. (2017). Possibilities of Utilizing Biotechnology to Improve Animal and Animal Feeds Productivity in Tanzania–Review of Past Efforts and Available Opportunities. *J Dairy Vet Anim Res*, *5*(5), 00155.

Rojas-Downing, M. M., Nejadhashemi, A. P., Harrigan, T., andWoznicki, S. A. (2017). Climate change and livestock: Impacts, adaptation, and mitigation. *Climate Risk Management*, *16*, 145-163.

Nardone, A., Ronchi, B.,Lacetera, N., Ranieri, M. S., andBernabucci, U. (2010). Effects of climate changes on animal production and sustainability of livestock systems. *Livestock Science*, *130*(1), 57-69.

Nosetto, M. D., Jobbágy, E. G., Tóth, T., and Jackson, R. B. (2008). Regional patterns and controls of ecosystem salinization with grassland afforestation along a rainfall gradient. *Global Biogeochemical Cycles*, *22*(2).

Sejian, V., Gaughan, J. B., Raghavendra Bhatta1 and Naqvi, S. M. K. (2016) Impact of climate change on livestock productivity. www.feedipediea.org.

Shantharaja, C. S., Bhatt, R. K. and Rajora M. P (2015) Phenotypic variability of Cenchrusciliaris L. germplasm in field gene bank.*Biodiversity, conservation and genetic improvement of range and forage species*. ICAR-Central Arid Zone Research Institute, Jodhpur, India.

Singh, L. P., Singh Gill, S., andTuteja, N. (2011). Unraveling the role of fungal symbionts in plant abiotic stress tolerance. *Plant Signaling andBehavior*, *6*(2), 175–191.

Thornton, P. K. (2010). Livestock production: recent trends, future prospects. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *365*(1554), 2853-2867.

Thornton, P. K., Van de Steeg, J., Notenbaert, A., and Herrero, M. (2009). The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. *Agricultural Systems*: 101(3), 113-127.

Tisdell, C. (2003). Socioeconomic causes of loss of animal genetic diversity: analysis and assessment. Ecological Economics, 45(3), 365-376.

United Nations Population Prospects (UNPP), (2018). Worldometers, Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2006 Revision and World Urbanization Prospects: The 2005 Revision.

Verslues, P. E., Agarwal, M., Katiyar, Agarwal, S., Zhu, J., and Zhu, J. K. (2006). Methods and concepts in quantifying resistance to drought, salt and freezing, abiotic stresses that affect plant water status. *The Plant Journal*, *45*(4), 523-539.