International Journal of Bioresource Science
Citation: IJBS: **09**(01): 01-08, June 2022
DOI: 10.30954/2347-9655.01.2022.1

ASSOCIATION FOR AGRICULTURE ENVIRONMENT AND BIOTECHNOLOGY

Review Paper

Current Status and Prospects of Improving Sunflower Production in Tanzania Through Intercropping with Sunn Hemp

Luciana R. Chappa[1*], Jayne Mugwe[1], Sagar Maitra[2] and Harun I. Gitari[1]

[1]Department of Agricultural Science and Technology, School of Agriculture and Enterprise Development, Kenyatta University, Nairobi, Kenya
[2]Centurion University of Technology and Management, Odisha, India

[*]Corresponding author: lucianachappa@gmail.com (**ORCID ID:** 0000-0002-3289-7989)

Received: 12-02-2022 **Revised:** 21-05-2022 **Accepted:** 03-06-2022

ABSTRACT

This paper highlights the importance of sunflower, and its current status, giving the prospects of improving its production through intercropping it with sunn hemp legume. The review focuses on Tanzania, where smallholder farmers mainly produce sunflower as a cash crop and a source of vegetable oil. The crop's production is threatened by decreased soil fertility, attack by pests and disease, limited rainfall, and the high cost of inputs like fertilizers and chemicals. This calls for adopting farming systems that can meet the increasing demand for sunflowers. Intercropping sunflower with a legume such as sunn hemp is an environmentally friendly technique for increasing and sustaining the productivity of the farmland.

HIGHLIGHTS

- Sunflower is a critical raw material in producing edible vegetable oil, as biodiesels, cosmetics, lubricants, paints, and drugs, besides being a source of livestock feeds.
- Factors affecting sunflower production include decreased soil fertility, attack by pests and disease, inadequate rainfall, and high cost of inputs such as fertilizers.
- Integrating sunn hemp into sunflower cropping systems can boost crop production while contributing to soil fertility.

Keywords: Intercropping, legume, sunflower, sunn hemp, soil fertility

Sunflower, which is botanically referred to as *Helianthus annuus* is an annual crop characterized by a large inflorescence flowering head. It's called a sunflower because its head takes the shape of the sun (Scherr and McNeely, 2008). Sunflower is characterized by an irregular stem that is hairy with coarsely notched leaves, with a circular head with approximately 1000 to 2000 flowers connected by only one receptacle base (Malézieux *et al.* 2009). Based on the variety, the crop can grow up to the height of 4.5 m, with the head measuring up to 30 cm in diameter (Muok *et al.* 2010). Like palm oil and groundnuts, sunflower is taken as one among the potential substitute source of the old fangled vegetable oil in the tropics (Ogunremi, 2000).

Even though sunflower is grown on every continent, the largest crop producers include Argentina, Eastern Europe, the European Union, the United States of America (USA), India, and China. Between 1997 and 2002, the USA accounted for about 10% of the global sunflower production (Oil *et al.*

How to cite this article: Chappa, L.R., Mugwe, J., Maitra, S. and Gitari, H.I. (2022). Current Status and Prospects of Improving Sunflower Production in Tanzania Through Intercropping with Sunn Hemp. *Int. J. Bioresource Sci.*, **09**(01): 01-08.

Source of Support: None; **Conflict of Interest:** None

2014). Between 1997 and 2004, sunflower ranked fifth behind soybeans, rapeseed, cottonseed, and peanuts. In 2015, the global sunflower production was roughly 40 million metric tons (FAOSTAT, 2015). Tanzania is rated position 10 worldwide among the major producers of sunflower seeds and second in Africa (Salisali, 2012; FAOSTAT, 2015). In Tanzania, sunflower is produced in fifteen regions: Singida, Iringa, Dodoma, Manyara, and Rukwa, with capacities of 40, 13.83, 12.35, 11.91, and 11.18%, respectively (URT, 2012).

Sunflower is considered one of the drought-tolerant crops because of its deep, extensive taproot system, which can extend beneath the average rooting depth of most annual crops to extract water and nutrients (Acland, 1971). García-Vila *et al.* (2012) showed that this crop is cultivated under both arid and semi-arid climatic conditions whereby it can be under irrigation or rainfed. When under irrigation, normally sprinkler and furrows irrigation methods are the crop's most preferred and common irrigation practices. It is worth noting that this crop requires only a limited amount of water (~ 50 mm) as supplemental irrigation (Casadebaig *et al.* (2011).

Given that most farmers cannot afford fertilizers, sunflower ought to be intercropped with legumes that offer many benefits, including mitigation of greenhouse gas emission, atmospheric N fixation, and contravention of pests and weeds cycle (Lemke *et al.* 2007). Henceforward, to maintain the food and nutritional security and sustain the agricultural activity, legume inclusion in cropping systems should be considered. Meena *et al.* (2015), Panda *et al.* (2020), and Raza *et al.* (2021), in their studies, reported multiple benefits of legume intercropping, which include enhancement of soil fertility by solubilization of fixed phosphorus and nitrogen fixation besides being able to decrease different abiotic and biotic stresses in the cropping systems like weeds, pests, and diseases. The use of legumes reduces the over-dependence on agricultural chemicals, and this is important in organic farming and a sustainable production system (Verma *et al.* 2015; Maitra *et al.* 2021).

Compared to monoculture, the addition of legumes in agricultural production can help to overcome the high price of agricultural inputs like fertilizers since such companion crops increase the accessibility and availability of nitrogen, potassium, and phosphorus in the soil (Huang, 2007; Stagnari *et al.* 2017). The reduction of tillage and fertilizers needs is essential in reducing the emission of greenhouse gases, lowering the problem of soil acidification and eutrophication in water bodies (Clark *et al.* 2013), and increasing soil Carbon sequestration (Reckling *et al.* 2014). Legumes have a significant role in increasing system productivity and enhancing resource use efficiency compared to pure stand (Faridvand *et al.* 2021; Jena *et al.* 2022). Sousa *et al.* (2022) in their study explained that sustainable agriculture involves the use of technologies that aim at increasing the availability of N, in which legumes and particularly beans were highlighted as key contributors to the ecological and economic sustainability of production systems.

There are different cropping systems in sunflower production, which can take both relay, row, and strip intercropping systems (Robinson, 1984). Compared with sole crops, intercropping sunflower with legumes is often regarded as highly important because it increases land productivity. For instance, intercropping sunflower with soybeans was shown to improve the productivity of the soil, and that phenomenon was attributed to the complementary use of resources among the two companion species (Andrade *et al.* 2012; Echarte *et al.* 2011).

SUNFLOWER PRODUCTION AND DISTRIBUTION IN TANZANIA

Tanzania is one of the nations that produce sunflowers in the world. The crop is used to produce edible cooking oil, which is cholesterol-free; after processing, the by-product is used as feed for livestock. Currently, about 13% of edible oil in the world is from sunflowers. The sunflower was brought to Tanzania by colonialists during the colonial era. It adapts and grows well in approximately all parts of the country, as opposed to other sources of vegetable oil crops such as palm oil that are location specific (Fernández-Luqueño *et al.* 2014). Fascinatingly, compared to other crops like wheat and maize, a sunflower grows well in the semi-arid areas, including the Central regions of Tanzania. Sunflower is grown by small farmers to improve their living standards.

Though there is a high production of other oilseeds like sesame and groundnuts, there has been low oil production from such crops. Most farmers prefer

to sell raw sesame and groundnuts for other uses instead of processing them for oil. Since the crops mentioned above have various uses compared to sunflower, makes sunflower oil remains the most vital vegetable oil produced in Tanzania (Fernández-Luqueño *et al.* 2014). Rathore (2001) reported that oil derived from sunflower is called premium oil since it has a high level of unsaturated fatty acid, containing up to 60% of polyunsaturated fatty acid. Such an attribute makes sunflower oil the most preferred vegetable oil used in diets since it helps reduce cholesterol levels in the blood.

Due to decreased soil fertility and the high price of farm inputs like fertilizers, sunflower production in Tanzania can not keep up with the rapidly growing population and external markets. In that case, innovations like intercropping sunflower with legumes such as sunn hemp can increase sunflower production and utilization of natural resources (Andrade *et al.* 2012; Echarte *et al.* 2011).

Economic importance of sunflower

Sunflower is one of the vegetable oils crops, with many benefits, such as being a source of nutritional food for humans and having its seed cake involved in animal feed preparations as an ingredient (Malik *et al.* 2017). Of essence to note is that after processing, 36% by mass of sunflower cake and meal contain about 45-50% protein content (Oliveira *et al.* 2016; Malik *et al.* 2017). Sunflower meal is comprised of minerals, vitamin B, and amino acids, besides being characterized by a high antioxidant content, which is captivating nutritious food meant for humans and the ingredients for animal feeds like chicken and pigs (Wanjari and Waghmare, 2015). As one of the promising protein sources in food preparation, sunflower seeds can be prepared as a substitute for soybeans, whose production is limited (Oliveira *et al.* 2016). Its seeds can be processed into various forms like flour, roasted, baked, or boiled as a composite functional meal (Wanjari and Waghmare, 2015; Grasso *et al.* 2019). The oil obtained from sunflower seeds is being consumed by many households. In addition, it is a raw material in food industries for making butter, snacks, margarine, and bread (Kottapalli *et al.* 2020).

Several parts of sunflowers have been diagnosed to be competent in traditional medications in the treatments of various health problems such as sores, dysentery, diarrhea, cough, and skin rashes (Mohiuddin, 2019). Processed sunflower seeds contain dietary fiber, fatty acid, high protein, vitamins, and minerals, and it's the source of antioxidants with low carbohydrates (Shahbaz *et al.* 2018). The nutritious components of the sunflower oils determine their functional characteristics, and they are also active in avoiding human illnesses like coronary heart disease, cancer, hypercholesterolemia, hypertension, and diabetes (Katsarou *et al.* 2015).

Sunflower is not only involved in the production of edible vegetable oil, but it is also a source of raw materials in the production of many products such as biodiesels, cosmetics, lubricants, paints, and drugs (Rocha-Filho *et al.* 2016). In addition, Muok *et al.* (2010) reported that sunflower oil is useful in making varnishes and paints since its oil has a better drying feature which does not have any effect on the color of the polished surface.

Factors affecting sunflower production

Sunflower production is being hindered by many factors, which can be biotic or abiotic. In general, its production challenges include decreased soil fertility, lack of improved seed varieties, unpredictable rainfall, low rainfall, undependable markets, price fluctuations, and the high price of agricultural inputs (such as fertilizers and chemicals). Others are pests, diseases, poor agricultural extension services, lack of awareness, absence of farm machinery, attacks by birds, competition from edible oil imports, and extreme weather conditions (Adeleke and Babalola, 2020).

During the cultivation period of sunflower, various diseases such as leaf spots, rusts, stem rots, head rots, root rots, and white blisters can emerge. Still,they can be eliminated easily using different farm practices such as crop rotation, biopesticides, and irrigation (Ebrahimian *et al.* 2019). Climate change is another factor causing significant effects on sunflower production and yields. That is, due to inadequate rainfall, the water supply to the crops is limited, which ultimately results in low yields.

Lack of knowledge and information involving sunflower cultivation, processing, and marketing creates many difficulties for farmers. More and adequate information about planting, seed rate,

the type and quantity of fertilizers to be applied, disease and pest control, and marketing availability is vital to attaining optimal yield in sunflower farming (Gupta, 2014). Birds, insects, and rodents' attacks might lead to vast loss to the sunflower in the field. Human beings can also cause the loss of sunflower outputs by plucking the flowers due to their captivating and beautiful look, resulting in both quantity and quality yield loss (Adeleke and Babalola, 2020).

GENERAL INFORMATION ABOUT SUNN HEMP PRODUCTION

Sunn hemp, botanically referred to as *Crotalaria juncea*, L. is one of the tropical legumes that originated in India about 400 B.C. It was first introduced in Europe by the years 1791 and 1792. The world's largest producers of sunn hemp include China, India, Bangladesh, and Brazil. It's also produced in other countries like Romania, the United States, Russia, CIS countries, Korea (DPR), and Pakistan (Chaudhury *et al.* 1997). Cook and White. 1996 reported that the first research in the United States involving sunn hemp was done in the 1930s. The tropic sunn was introduced in the U.S. to be used as a green manure crop or warm-season cover crop (Mansoer *et al.* 1997).

Sunn hemp has long taproots with lobbed nodules and a stem almost 2 cm in diameter. It's characterized by an open raceme inflorescence, with its flowers containing five hairy sepals and deep yellow petals. The crop matures between 60 and 90 days after planting, producing small flattened, dark grey to black seeds. Within sixty days it can grow up to the height of 6 feet, producing a lot of organic matter up to 4 tons per ha. The crop can fix nitrogen and transfer the residual potash and phosphorus from the deeper soil layers to the upper horizons. Sunn hemp grows well in dry regions with well-drained sandy soils characterized by a pH of 5-8.2 (Acland, 1971). It adapts well to soils that range from coarse to fine-textured, as well as to both infertile and fertile soils. In addition, this crop adapts well to variable amounts of rainfall.

Economic importance of sunn hemp

Sunn hemp is generally utilized as green manure to improve soil fertility because it can produce high amounts of biomass within a few days, between 60 and 90 days, by which the plant can reach a height of 4 to 6 feet (USDA, 1999). As a legume, sunn hemp fixes typically a large amount of nitrogen, making the soil more fertile. Rotar and Joy (1983) and Mansoer *et al.* (1997) reported that sunn hemp adds about 140 and 126 pounds of N per acre, respectively, after 60 to 70 days of its growth. Thus, this is an indication that a large amount of N is being produced hence a crop like a sunflower ought to follow sunn hemp to exploit the symbiotically fixed N. The study that was conducted by Mansoer *et al.* (1997) showed that 38% of the N in biomass continued to be available for maize that was planted 16 weeks after mowing the sunn hemp.

Sunn hemp gives a similar advantage to grass cover crops, which consist of increasing organic carbon contents, improving water infiltration, erosion control, the addition of nitrogen by biological nitrogen fixation, and cooling soil temperatures (Reeves, 1994), The nitrogen provided by the sunn hemp can decrease nitrogenous fertilizers requirements (Ebelhar *et al.* 1984; Holderbaum *et al.* 1990).

Ribas *et al.* (2003) reported that sunn hemp intercropped with okra demonstrated higher productivity than the non-intercropped okra. The study conducted by Oliveira *et al.* (2007) revealed that intercropping taro with sunn hemp increased the amount of nitrogen in the system, whereby 211 kg ha^{-1} of N was observed, correspondingly sunn hemp indorsed the cycling of nutrients to an average of 17, 85, 151 and 27 kg ha^{-1} of phosphorus, potassium, calcium, and magnesium, respectively. This tropic legume can produce huge amounts of biomass and symbiotic nitrogen in an eight to twelve weeks' frost-free period (Wang *et al.* 2011). Compared with other cover crops such as velvet bean (*Mucuna pruriens*) and cowpea (*Vigna unguiculata*), sunn hemp accumulates a high amount of phosphorus (P) and nitrogen (N) because it produces a high amount of biomass (Wang *et al.* 2011).

Sunn hemp can also as serve as a cover crop preventing soil erosions and improving soil properties hence conserving soil water and nutrients. Rotar and Joy. (1983) reported that Sunn hemp can equally be used as a forage crop, used in making paper fiber, and a substitute for fuel crops. In India, the crop is reported to be drought-tolerant, adapting

to various soils. It improves and modifies the soil condition, adds nitrogen to the soil, produces huge organic matter, which is beneficial to the soil, resists root-knot nematodes, and suppresses weeds. It is not an alternate host of diseases and pests affecting commercial crops and producing high seed yields (Rotar and Joy, 1983).

IMPORTANCE OF SUNFLOWER-SUNN HEMP INTERCROPPING

Intercropping refers to the concurrent cultivation of at least two kinds of crops grown in an area in which there is optimal use of resources (water, nutrients, carbon dioxide, light, etc) throughout the season or part of their growing season (Madani *et al.* 2018; Gitari *et al.* 2020). According to Baumann. (*et al*. 2001), it is a component of sustainable agriculture in which the degree of biodiversity is high with resultant biological stability. As opposed to monocropping, which is normally practiced in large-scale agriculture, and involves heavy use of machines, smallholder farmers prefer intercropping as they target to produce food to sustain their families (Ochieng *et al.,* 2021; Mwadalu *et al.,* 2022). Intercropping practice is essential since it produces stable yields, with only a few inputs for nutrients additions, pest and disease control are required. Yet, it has an ultimate goal of maintaining soil fertility (Maitra *et al.,* 2021).

Gitari *et al.* (2018b, 2020), Jena *et al.* (2022), and Nyawade *et al.* (2019a, b) have reported that legume intercropping is one of the climate-smart cropping practices useful to small-scale farmers with high climatic related risks diversification. In their studies, Nyawade *et al.* (2020), reported that intercropping legumes reduces soil and nutrients loss besides enhancing ground cover establishment and increasing crop yields. Saudy and Elmetwally (2009) reported that one tactic to increase field crop yields is intercropping. Under intercropping, the companion crops use nutrients, water, and light more efficiently (Babec *et al.* 2020; Zhang and Li, 2003; Gitari *et al.* (2018a). Cover crops under intercropping improve not only the chemical properties but also the biological properties of the soil, with resultant high production of the subsequent crop (Batista *et al.* 2019). Intercropping is good for weeds, diseases, pest suppression, and soil erosion control (Batista *et al.* 2019).

When intercropped with legumes such as sunn hemp, there are many benefits, including soil erosion control, enhanced water infiltration, and improved soil fertility (Reeves, 1994; Balkcom and Reeves, 2005). High yields can be attained when crop species are intercropped than when the crops are cultivated under monoculture (Beckage and Gross, 2020). Multi-cropping systems which involve legumes can lead to symbiotic nitrogen fixation and a rise in crop yield through better and more efficient use of a resource such as water, light, and nutrients (Jena *et al.* 2022; Gitari *et al.* 2020; Nyawade *et al.* 2020; Maitra and Gitari 2020). Most the legumes increase organic matter quantities, which support biological activity in the soil, hence raising the nutrient availability (Batista *et al.* 2019; Nyawade *et al.* 2019c). Nonetheless, from various literature and to the best of our understanding, the intercropping between sunflower and legumes, particularly sunn hemp, is quite rare. Given that various merits are associated with such a cropping system, as noted in this review, farmers ought to adopt the practice of integrating sunn hemp into their sunflower farming.

CONCLUSION

This review has disclosed challenges encountering the production of sunflowers in Tanzania, which include decreased soil fertility, lack of improved sunflower seeds varieties, unpredictable/low rainfall, undependable markets, price fluctuations, the high price of agricultural inputs (such as fertilizers, chemicals, and machinery), pests, diseases, and poor agricultural extension. Sunflower is grown mainly by poor smallholder farmers who cannot afford the fertilizers to replenish the decreased nutrients in the soil. Therefore, intercropping sunflower with legumes like sunn hemp provides a sustainable crop production option. Intercropping with legumes such as sunn hemp is cost-effective and doesn't support pest attack and disease establishment besides having the legume fixing a considerable amount of nitrogen, which can decrease nitrogenous fertilizers requirements.

REFERENCES

Acland, J.D. 1971. East African crops: An introduction to the production of field and plantation crops in Kenya, Tanzania, and Uganda. Longman Group UK Limited, Essex.

Adeleke, B.S. and Babalola, O.O. 2020. Oilseed crop sunflower (*Helianthus annuus*) as a source of food: Nutritional and health benefits. *Food Sci. Nutr.*, **8**(9): 4666–4684.

Andrade, J.F., Cerrudo, A., Rizzalli, R.H. and Monzon, J.P. 2012. Sunflower–soybean intercrop productivity under different water conditions and sowing managements. *Agron. J.*, **104**(4): 1049–1055.

Babec, B., Šeremešić, S., Hladni, N., Terzić, S., Vojnov, B., Ćuk, N. and Gvozdenac, S. 2020. Effect of intercropping sunflower with legumes on some sunflower morphological traits. *Ratarstvo i Povrtarstvo*, **57**(2): 61–67.

Balkcom, K.S. and Reeves, D.W. 2005. Sunn-hemp utilized as a legume cover crop for corn production. *Agron. J.*, **97**(1): 26–31.

Batista, V.V., Hossa, R.A., Lemes, E.S., Oligini, K.F., Barhy, C.A. and Adami, P.F. 2019. Methods of intercropping cover crops with maize in Southern Brazil. *J. Agron.*, **19**(1): 14–23.

Baumann, D.T., Bastiaans, L. and Kropff, M.J. 2001. Competition and crop performance in a leek–celery intercropping system. *Crop Sci.*, **41**(3): 764–774.

Beckage, B. and Gross, L.J. 2020. Overyielding and species diversity: what should we expect? *New Phytol.*, **172**: 140–148.

Casadebaig, P., Guilioni, L., Lecoeur, J., Christophe, A., Champolivier, L. and Debaeke, P. 2011. SUNFLO, a model to simulate genotype-specific performance of the sunflower crop in contrasting environments. *Agric. For. Meteorol.*, **151**(2): 163–178.

Chaudhury, J., Singh, D.P. and Hazra, S.K. 1997. Sunnhemp (*Crotalaria juncea*, L). Central Res. Inst. Jute Allied Fibres, ICAR, India.

Clark, C.M., Yongfei, B., Bowman W.D., Cowles M.J, Fenn, M.E., Gilliam, F.S., Phoenix, G.K., Ilyas, S., Stevens C.J., Sverdrup, H.U. and Throop, H.L. (2013). Nitrogen deposition and terrestrial biodiversity. *In:* Levin, S.A. (Ed) Encyclopedia of biodiversity, vol 5, 2nd edn. Academic, Waltham, pp. 519–536.

Cook, C.G. and White, G.A. 1996. Crotalaria juncea: A potential multipurpose fiber crop. *Progress in New Crops.*

Ebelhar, S.A., Frye, W.W. and Blevins, R.L. 1984. Nitrogen from Legume Cover Crops for No- Tillage Corn 1. *Agron. J.*, **76**(1): 51–55.

Ebrahimian, E., Seyyedi, S.M., Bybordi, A. and Damalas, C.A. 2019. Seed yield and oil quality of sunflower, safflower, and sesame under different levels of irrigation water availability. *Agric. Water Manag.*, **218**: 149–157.

Echarte, L., Della, M.A., Cerrudo, D., Gonzalez, V. H., Abbate, P., Cerrudo, A. and Calvino, P. 2011. Yield response to plant density of maize and sunflower intercropped with soybean. *Field Crops Res.*, **121**(3): 423–429.

FAOSTAT- Food and Agricultural Organisation Statistics 2015. Production of sunflower seeds in Tanzania. Available online at http://www.faostat.org.

Faridvand, S., Rezaei-Chiyaneh E., Battaglia, M., Gitari, H., Raza, M.A. and Siddique, K.H.M. 2021. Application of bio and chemical fertilizers improves yield, and essential oil quantity and quality of Moldavian balm (*Dracocephalum moldavica* L.) intercropped with mung bean (*Vigna radiata* L.). *Food and Energy Secur.* https://doi.org/10.1002/fes3.319.

Fernández-Luqueño, F., López-Valdez, F., Miranda-Arámbula, M., Rosas-Morales, M., Pariona, N. and Espinoza-Zapata, R. 2014. An Introduction to the Sunflower Crop. *In:* Arribas, J. I (Ed.) Sunflowers. *Nova Science Publishers*, Inc. USA.

García-Vila, M., Fereres, E., Prieto, M.H., Ruz, C. and Soriano, M.A. 2012. Sunflower. *In:* Steduto, P., Hsiao, T.C., Fereres, E., Raes, D. (eds) Crop Yield Response to Water. FAO, Rome, pp. 164–173.

Gitari, H.I., Gachene, C.K.K., Karanja, N.N., Kamau, S., Nyawade, S., Sharma, K. and Schulte-Geldermann, E. 2018a. Optimizing yield and economic returns of rain-fed potato (*Solanum tuberosum* L.) through water conservation under potato-legume intercropping systems. *Agric. Water Manag.*, **208**: 59–66.

Gitari, H.I., Karanja, N.N., Gachene, C.K.K., Kamau, S., Sharma, K. and Schulte-Geldermann, E. 2018b. Nitrogen and phosphorous uptake by potato (*Solanum tuberosum* L.) and their use efficiency under potato-legume intercropping systems. *Field Crops Res.*, **222**: 78–84.

Gitari, H.I., Nyawade, S.O., Kamau, S., Karanja, N.N., Gachene, C.K.K., Raza, M.A., Maitra, S. and Schulte-Geldermann, E. 2020. Revisiting intercropping indices with respect to potato-legume intercropping systems. *Field Crops Res.*, **258**: 107957.

Grasso, S., Omoarukhe, E., Wen, X., Papoutsis, K. and Methven, L. 2019. The use of upcycled defatted sunflower seed flour as a functional ingredient in biscuits. *Foods*, **8**(8): 305.

Gupta, M.K. 2014. Sunflower oil and its applications. *Lipid Technology*, **26**(11–12): 260–263.

Huang, W.Y. 2007. Impact of rising natural gas prices on U.S. ammonia supply, Outlook Report No. (WRS- 0702). USDA Economic Research Service, Washington, DC, pp. 18.

Jena, J., Maitra, S., Hossain, A., Pramanick, B., Gitari, H.I., Praharaj, S., Shankar, T., Palai, J.B., Rathore, A., Mandal, T.K. and Jatav., H.S. 2022. Role of Legumes in Cropping System for Soil Ecosystem Improvement. *In:* Jatav, H.S., Rajput, V.D. (Ed.). Ecosystem Services: Types, Management and Benefits. *Nova Science Publishers*, Inc. USA.

Lemke, R.L., Zhonga, Z., Campbell, C.A. and Zentner, R. 2007. Can pulse crops play a role in mitigating greenhouse gases from north American agriculture. *Agron. J.*, **99**(6): 1719–1725.

Madani, H., Gomarian, M. and Hosseini, S.R.M. 2018. *J. Crop Nut. Sci.*, **4**(1): 1–14.

Maitra, S. and Gitari, H. 2020. Scope for adoption of intercropping system in Organic Agriculture. *Indian J. Nat. Sci.*, **11**(63): 28624–28631.

Maitra, S., Hossain, A., Brestic, M., Skalicky, M., Ondrisik, P., Gitari, H., Brahmachari, K., Shankar, T., Bhadra, P.,

Palai, J.B., Jena, J., Bhattacharya, U., Duvvada, S.K., Lalichetti, S. and Sairam, M. 2021. Intercropping—A Low Input Agricultural Strategy for Food and Environmental Security. *Agron.*, **11**(2): 343.

Malézieux, E., Crozat, Y., Dupraz, C., Laurans, M., Makowski, D., Ozier-Lafontaine H., Rapidel, B., de Tourdonnet, S. and Morison, M. 2009. Mixing plant species in cropping systems: Concepts, tools and models. A review of Agronomics. *Sustain. Dev.*, **29**: 43-62.

Malik, M.A., Sharma, H.K. and Saini, C.S. 2017. High intensity ultra- sound treatment of protein isolate extracted from dephenolized sunflower meal: Effect on physicochemical and functional properties. *Ultras. Sonochem.*, **39**: 511–519.

Mansoer, Z., Reeves, D.W. and Wood, C.W. 1997. Suitability of sunn hemp as an alternative late-summer legume cover crop. *Soil Sci. Soc. Am. J.*, **61**(1): 246-253.

Meena, R.S., Meena, V.S., Meena, S.K. and Verma, J.P. 2015. Towards the plant stress mitigate the agricultural productivity: a book review. *J. Clean Prod.*, **102**: 552–555.

Mohiuddin, A. 2019. Indigenous plants as sources of pharmacological interests. *J. Global Biosci.*, **8**(1): 5900–5915.

Muok, B.O., Nyabenge, M., Ouma, B.O., Esilaba, A.O., Nandokha, T. and Owuor, B. 2010. Environmental suitability and agro-environmental zoning of Kenya for biofuel production. Assessed from https://www.eldis.org on March 11, 2022.

Oliveira, F.L., Guerra, J.G.M., Ribeiro, R.D.L.D., De Almeida, D.L., Da Silva, E.E., Urquiaga, S. and Espindola, J.A.A. 2007. The use of sunn hemp as green manure intercropped with taro. *Hort. Brasileira.*, **25**(4): 562–566.

Holderbaum, J.F., Decker, A.M., Messinger, J.J., Mulford, F.R. and Vough, L.R. 1990. Fall-seeded legume cover crops for no-tillage corn in the humid east. *Agron. J.*, **82**(1): 117–124.

Katsarou, A.I., Kaliora, A.C., Papalois, A., Chiou, A., Kalogeropoulos, N., Agrogiannis, G. and Andrikopoulos, N.K. 2015. Serum lipid profile and inflammatory markers in the aorta of cholesterol-fed rats supplemented with extra virgin olive oil, sunflower oils and oil products. *Int. J. Food Sci. Nutr.*, **66**(7): 766–773.

Kottapalli, B., Nguyen, S.P., Dawson, K., Casulli, K., Knockenhauer, C. and Schaffner, D.W. 2020. Evaluating the risk of Salmonellosis from dry roasted sunflower seeds. *J. Food Prot.*, **83**(1): 17–27.

Nyawade, S.O., Gachene, C.K.K., Karanja, N.N., Gitari, H.I., Schulte-Geldermann, E. and Parker, M. 2019a. Controlling soil erosion in smallholder potato farming systems using legume intercrops. *Geoderma Reg.*, **17**: e00225.

Nyawade, S.O., Karanja, N.N., Gachene, C.K.K., Gitari, H.I., Schulte-Geldermann, E. and Parker, M. 2019b. Intercropping optimizes soil temperature and increases crop water productivity and radiation use efficiency of rainfed potato. *Am. J. Potato Res.*, **96**(5): 457–471.

Nyawade, S., Gitari, H.I., Karanja, N.N. and Gachene, C.K.K. 2020. Enhancing climate resilience of rain-fed potato through legume intercropping and silicon application. *Front. Sustain. Food Syst.*, **4**: 566345.

Nyawade, S.O., Karanja, N.N., Gachene, C.K. K., Gitari, H.I., Schulte-Geldermann, E. and Parker, M.L. 2019c. Short-term dynamics of soil organic matter fractions and microbial activity in smallholder legume intercropping systems. *Appl. Soil Ecol.*, **142**: 123–135.

Ochieng', I.O., Gitari, H.I., Mochoge, B., Rezaei-Chiyaneh, E. and Gweyi-Onyango, J.P. 2021. Optimizing maize yield, nitrogen efficacy and grain protein content under different N forms and rates. *J. Soil Sci. Plant Nutr.*, **21**(3): 1867–1880.

Ogunremi, E.A. 2000. Sunflower, Kenaf, and sugar cane in Nigeria: My experiences in agronomy in Nigeria. M, Akoroda (Ed.), University of Ibadan, Ibadan Nigeria, pp. 130–142.

Oil, V., Acids, F., Gulya, T.J., Europe, E., Union, E. and Randle, B.A.C. 2014. *Helianthus annuus Sunflower*. Sunn Hemp. *Forage Soil- Build. Superhero*. 1–6.

Oliveira, V.R., de Arruda, A.M.V., Silva, L.N.S., de Souza Jr, J.B.F., de Queiroz, J.P.A.F., da Silva Melo, A. and Holanda, J.S. 2016. Sunflower meal as a nutritional and economically viable substitute for soybean meal in diets for free-range laying hens. *Animal Feed Sci. Technol.*, **220**: 103–108.

Panda, S.K., Panda, P., Pramanick, B., Shankar, T., Praharaj, S., Saren, B.K., Gitari, H.I., Brahmachari, K., Hossain, A. and Maitra, S. 2020. Advantages of cotton based intercropping system: A review. *Int. J. Biores. Sci.*, **7**(2): 51–57.

Rathore, P.S. 2001. Techniques and management of field crop production. *Agrobis, India*.

Raza, M.A., Gul, H., Wang, J., Yasin, H.S., Qin, R., Khalid, M.H.B., Naeem, M., Feng, L.Y., Iqbal, N., Gitari, H., Ahmad, S., Battaglia, M., Ansar, M., Yang, F. and Yang, W. 2021. Land productivity and water use efficiency of maize-soybean strip intercropping systems in semi-arid areas: A case study in Punjab Province, Pakistan. *J. Cleaner Prod.*, **308**: 127282.

Reckling, M., Preissel, S., Zander, P., Topp, K., Watson, C., Murphy-Bokern, D. and Stoddard, F. L. 2014. Effects of legume cropping on farming and food systems. *Legume futures report* No. **1.6.**, Assessed from www.legumefutures.de on Apr 19, 2022.

Reeves, D.W. 1994. Cover crops and rotations, pp. 125–172. JL Hatfield and BA Stewart (ed.) Crop residue management. *Adv. Soil Sci. Lewis Publ.*, Boca Raton, FL. Cover crops rotations, pp. 125–172. *In* JL Hatfield and BA Stewart (Eds.) Crop residue management. *Adv. Soil Sci. Lewis Publ., Boca Raton, FL.*

Ribas, R.G.T., Junqueira, R.M., Oliveira, F.D., Guerra, J.G.M., Almeida, D.D., Alves, B.J.R. and Ribeiro, R.D.L. 2003. Desempenho do quiabeiro (*Abelmoschus esculentus*) consorciado com *Crotalaria juncea* sob manejo orgânico. *Agronomia*, **37**(2): 80–84.

Robinson, R.G. 1984. Sunflower for Strip, Row, and Relay Intercropping 1. *Agron. J.*, **76**(1): 43–47.

Rocha-Filho, D., Alves, P., Maruno, M., Ferrari, M. and Topan, J.F. 2016. Liquid crystal formation from sunflower oil: Long term stability studies. *Molecules*, **21**(6): 680.

Rotar, P.P. and Joy, R.J. 1983. Tropic sun (Sunn hemp) *Crotalaria juncea* L. *College of Tropical Agric. Human Res.*, **36**(11): 1–11.

Salisali, B. 2012. Sunflower Sector Project Implementation 2006-2012. Dodoma, Rural Livelihood Development Programme.

Saudy, H.S. and El-Metwally, I.M. 2009. Weed management under different patterns of sunflower-soybean intercropping. *J. Central Eur. Agric.*, **10**(1): 41–51.

Scherr, S.J. and McNeely, J.A. 2008. Biodiversity conservation and agricultural sustainability: Towards a new paradigm of 'ecoagriculture' landscapes. *Philos Trans Royal Soc.*, **63**: 477–494.

Shahbaz, A.K., Lewińska, K., Iqbal, J., Ali, Q., Iqbal, M.M., Tauqeer, H.M. and Ramzani, P.M.A. 2018. Improvement in productivity, nutritional quality, and antioxidative defense mechanisms of sunflower (*Helianthus annuus* L.) and maize (*Zea mays* L.) in nickel contaminated soil amended with different biochar and zeolite ratios. *J. Environ. Manag.,* **218**: 256–270.

Sousa, W.S., Soratto, R.P., Peixoto, D.S., Campos, T.S., da Silva, M.B., Souza, A.G.V., Teixeira, I.R. and Gitari H.I. 2022. Effects of *Rhizobium* inoculum compared with mineral nitrogen fertilizer on nodulation and seed yield of common bean. A meta-analysis. *Agron. Sustain Dev.* In Press.

Stagnari, F., Maggio, A., Galieni, A. and Pisante, M. 2017. Multiple benefits of legumes for agriculture sustainability: an overview. *Chem. Biol. Technol. Agric.*, **4**: 2.

URT- United Republic of Tanzania, 2012. National Sample Census of Agriculture 2007/2008 Volume Vm: Regional Report-Singida Region. Dar es Salaam, Ministry of Agriculture, Food Security and Co-operatives.

USDA-United States Department of Agriculture. 1999. Sunn Hemp : A Cover Crop for Southern and Soil Quality. *Agron. Tech. Note*, **10***:* 10–13.

Verma, J.P., Jaiswal, D.K., Meena, V.S. and Meena, R.S. 2015. Current need of organic farming for enhancing sustainable agriculture. *J. Clean Prod.*, **102:** 545–547.

Wang, K.H., Sipes, B.S., Hooks, C.R.R. and Leary, J. 2011. Improving the status of sunn hemp as a cover crop for soil health and pests management. *Hanai 'Ai Newsletter*.

Wanjari, N. and Waghmare, J. 2015. Phenolic and antioxidant potential of sunflower meal. *Adv. Appl. Sci. Res.*, **6**: 221–229.

Zhang, F. and Li, L. 2003. Using competitive and facilitative interactions in intercropping systems enhances crop productivity and nutrient use efficiency. *Plant Soil*, **248**(1): 305–312.