



Impact of Various Nutrient Management Technique on Growth, Yield and Quality Attributes of Sweet Sorghum (*Sorghum bicolor* L.)

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ABSTRACT

Background: These studies aim to determine the influences of various organic and inorganic nutrient sources on the growth, yield and quality attributes of sweet sorghum within the Indo-Gangetic region.

Methods: The experiment utilized a randomized block design with ten treatments replicated three times. These treatments included various nutrient management strategies: two different doses of inorganic fertilizers (100% and 75% of the recommended dose) applied with or without zeolite, press-mud and bio-neema, as well as three foliar applications of nano NPK.

Result: Among the nutrient management strategies, the application of 75% of the recommended dose of fertilizers (RDF) along with zeolite, press-mud and bio-neema showed a superior and significant improvement. This strategy enhanced growth attributes such as plant height by 23.73% and dry matter accumulation by 42.25%. It also improved yield attributes, including ear head length by 31.34%, grain yield by 53.25% and test weight by 30.67%. Furthermore, this treatment increased the Brix ratio by 37.67% and the juice extraction percentage by 39.04% compared to the control. This study underscores the crucial role of strategic nutrient management in sweet sorghum cultivation, demonstrating the most promising outcomes for enhancing growth, yield and quality.

Key words: Bio-neema, Brix ratio, Juice extraction, Press-mud, Sweet sorghum, Zeolite.

INTRODUCTION

Sweet sorghum, specifically the species (*Sorghum bicolor* L.) has considerable potential as a bioethanol feedstock due to its juice richness and high biomass yield. Globally, sweet sorghum stands as the fifth most widely cultivated cereal grain, after wheat, rice, maize and barley, as reported by Namooobe *et al.* (2014). This versatile crop can be readily cultivated in areas with arid, semi-arid and salt-tolerant climates. In challenging conditions, it efficiently converts sunlight into high concentrations of carbohydrates and sugars and is commonly used for ethanol production (Zhang and Vesselinov, 2014). This crop exhibits distinctive traits, notably its grain yield and versatility in stem utilization, encompassing applications such as sugar production, alcohol, syrup, jaggery, roofing materials, fencing and paper manufacturing. About 70-80% of the biomass in sweet sorghum comes from its stalk, which is also the main part of the plant where its juice is stored. Characteristics of sweet sorghum include its quickly growing nature, adaptability and resistance to non-living environmental stressors like flooding, high salt levels, or lack of water (Arumugam *et al.*, 2025). Nitrogen is vital for plant development; therefore, sweet sorghum is a superior crop that reacts positively to nitrogen fertilizers, demonstrating a high level of nitrogen use efficiency compared to other cereal crops. A sufficient nutrient supply is crucial for maintaining steady growth, foliage development, internode expansion, plant stature and the buildup of dense components, like total dissolved solids (measured by the Brix ratio), spike length and the quantity of grains per spike

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(Ajeigbe *et al.*, 2018). The application of nano fertilizers can improve plant nutrient uptake and promote soil health and productivity for an extended period (Umesh *et al.* 2024). Therefore, they can navigate and travel more freely inside plants. They also contribute to minimizing nutrient waste, which benefits the soil, water, environment and tiny organisms in the soil. Research by Kopittke *et al.* (2019) discovered that applying nano fertilizers to leaves led to a rise in the nitrogen levels in the plants following the application (Roy *et al.*, 2019). The small particles, measuring 25-50 nanometers in width, enable the plants to retain essential nutrients and offer a greater surface area through which they can absorb these nutrients, according to Singh *et al.* (2025). Consequently, nano-NPK fertilizers can decrease nutrient loss as the nutrients are directly absorbed by the plant. In contrast, conventional phosphorus

fertilizers frequently become lodged in the soil and are not taken up efficiently (Sodavadiya *et al.*, 2023). A naturally occurring hydrated aluminosilicate mineral called zeolite is utilized as a soil amendment to accumulate nutrients and enhance soil properties through the reduction of water leaching, thereby conserving nutrients and water for crops. Zeolite can hold and storing significant amounts of water and nutrients, which can then be released to support plant growth, particularly when water conservation is necessary, as demonstrated by Khalifa *et al.* (2019). According to Ozbahce *et al.* (2015), incorporating zeolite into soil can have a positive impact on nutrient retention and utilization; combining mineral fertilizers with zeolite was shown to significantly boost nutrient absorption due to zeolite's high capacity for holding nutrients. Press-mud, a rich source of organic matter and nutrients, enhances soil fertility and can be profitably utilized for crop cultivation. As an organic fertilizer, press-mud provides vital nutrients and has a beneficial impact on the soil's physical, chemical and biological characteristics (Singh *et al.*, 2015). Bio-neema is used as a control agent for soil-borne pests and diseases due to the presence of azadirachtin alkaloids, which offer the ideal pesticide and save the environment and other natural enemies or pests. Therefore, the present study focuses on evaluating the impact of various combinations of organic and inorganic nutrients on the growth, yield and qualitative characteristics of sweet sorghum in the Indo-Gangetic region. This study aims to improve resource use efficiency, enhance crop performance and promote sustainable agricultural practices in sweet sorghum production technology.

MATERIALS AND METHODS

Experimental site

The study was conducted at Lovely Professional University Phagwara district of Kapurthala, Punjab, during the *kharif* season 2023-24. The experimental site is located at 31.°22' 31.81"N, 75.23°03.02"E, is part of the central plain zone of Punjab's agro-climatic regions, specifically within the trans-Gangetic plains of India, with an average elevation of 252 m above mean sea level. The area is characterized by slight rainfall distribution (545-655 mm) with a short rainy season happening from late July to end September and average temperature with high humidity an average sunlight 7.1 h. The topsoil (0-30 cm) of experimental site was characterized by a sandy clay loam texture class with, medium organic carbon (0.58), low nitrogen (239.30 @ kg ha⁻¹), medium phosphorus (P₂O₅ @ 29.3 kg ha⁻¹), available potassium (247.70 @ kg ha⁻¹) and pH (7.35). The design was randomized block design with three replicates and ten treatments combinations. The treatments details are as follows: T₁ with absolute control; T₂, 100% RDF (90:40:40: N, P₂O₅ and K₂O kg ha⁻¹); T₃, 75% RDF + Zeolite (1.5 t ha⁻¹); T₄, 75% RDF + Press-mud (15 t ha⁻¹); T₅, 75% RDF + zeolite (1.5 t ha⁻¹) + Press-mud (15 t ha⁻¹); T₆, 75% RDF + zeolite (1.5 t ha⁻¹) + Press-mud (15 t ha⁻¹) + Bio-neema (5 kg ha⁻¹); T₇, Nano NPK (19:19:19) + zeolite (1.5 t ha⁻¹);

T₈, Nano NPK (19:19:19) + Press-mud (15 t ha⁻¹); T₉, Nano NPK (19:19:19) + Press-mud (15 t ha⁻¹) + Zeolite (1.5 t ha⁻¹); T₁₀, Nano NPK (19:19:19) + zeolite (1.5 t ha⁻¹) + Press-mud (15 t ha⁻¹) + bio-neema (5 kg ha⁻¹). Fertilizers were applied the as per the recommended dose, using diammonium phosphate (DAP), urea and muriate of potash (MOP). Therefore, fertilizers doses were adjusted according to treatment specifications. Zeolite were applied at the time of sowing, Press-mud and Bio-neema was applied before one month sowing of the crop on dry basis and variety of SSV-84 used in experimental trail.

Juice extraction (%) =

$$100 \times \frac{\text{Stalk yield (Kg ha}^{-1}) - \text{Bagasses yield (Kg ha}^{-1})}{\text{Stalk yield (Kg ha}^{-1})} \quad \dots (1)$$

Statistical analysis

The data were analysed and interpreted using Fisher's analysis of variance method, as reported by Gomez and Gomez (1984). The least significant difference (LSD) was determined at a significance level of $p \leq 0.05$ with OPSTAT software used to compute the means of the treatments.

RESULTS AND DISCUSSION

Growth and growth attributes

At harvesting stage, the mean values of growth attributes in sweet sorghum were significantly influenced by the treatments (Table 1). The highest plant height (255.06 cm), dry matter accumulation (254.28 g), stem diameter (27.38 mm) and number of leaves per plant (17.08) were recorded under the T₆ treatment (75% RDF + zeolite (1.5 t ha⁻¹) + Press-mud (15 t ha⁻¹) + Bio-neema (5 kg ha⁻¹), followed by T₂ treatments (100% RDF) which was statistically at par with T₃ and T₅ treatments. It might be due to mineralization of nitrogen from inorganic fertilizers and steady supply of organic material like press mud and zeolite, influenced growth and growth attributes of the sweet sorghum. In Additionally primary macro-nutrient (N, P₂O₅, K₂O), zeolite and press-mud contain beneficial secondary metabolites nutrient, bioactive compound and plant growth hormones that boost plant strength by increase of nutrient absorption, root and stem development. These results were followed by Karimi (Karimi and Majma, 2015; Ramesh *et al.*, 2010). The SPAD value (Table 1) significantly was recorded in T₆ (45.54), followed by T₂ (44.45), which was statically on par with T₃ (40.82), T₅ (40.37) and T₁₀ (40.45) and lowest SPAD value was observed in T₁ (34.48), which was 24.28% lowest than the Superior SPAD value. It might be synergistic interaction between the organic compound (press-mud, bio-neema) and inorganic fertilizers (zeolite, N, P₂O₅ and K₂O). Furthermore, stimulate microbial activity of soil, therefor enhancing nutrient absorbability and availability in sweet sorghum plants (Ozbahce *et al.*, 2015; Anbarasu *et al.*, 2016). The findings showed a synergetic effect, suggesting a mutually beneficial influence on plant growth and development. The combined treatments contributed to an

increase in plant growth of sweet sorghum, which can be linked to the increased absorption of nutrients and water, as well as enhanced soil physical properties (Khaliq *et al.*, 2024). The combination of RDF, press-mud and zeolite, along with bio-organic materials like bio-neema, enables enhanced nutrient retention and reduced leaching, gradually releasing nutrients that complement the quick effects of inorganic fertilizers like urea, thereby contributing to a more balanced nutrient profile for plant uptake, which supports shoot and root development (Dubey *et al.*, 2019) and creates a favorable environment for beneficial microorganisms (Addeo *et al.*, 2023).

Yield and yield attributes

Significantly highest length of ear head (18.44 cm), number of spikelet's (42.93) and test weight (55.13 g per 1000

seeds), was recorded under the T₆ (75% RDF + zeolite (1.5 t ha⁻¹) + Press-mud (15 t ha⁻¹) + Bio-neema (5 kg ha⁻¹), followed by T₂ (16.33 cm, 41.44 and 46.55 g), which is statically at par with T₅, T₃ and T₄ treatments respectively (Table 2). The lowest value was recorded under the control treatment, which was 31.34% length of ear head, 37.15% number of spikelet's and, 30.67% test weight lower than the superior. The maximum sorghum yield was recorded under the T₆ (30.87 q ha⁻¹), followed by T₂ (30.12 q ha⁻¹), which was on par with T₅ (26.66 q ha⁻¹) treatments respectively, which's lowest grain yield was recorded under control T₁ (14.07 q ha⁻¹), which was representing a 53.28% reduction compared to the superior grain yield. It might be due to nutrient management techniques such as 75% recommended dose of fertilizers (RDF), zeolite, press-mud

Table 1: Effect of different nutrients management on plant height (cm), no. of leaves, dry matter accumulation (g), stem diameter (mm) and chlorophyll content (SPAD value).

Tr. no.	Plant height (cm)	Number of leaves (plant ⁻¹)	Dry matter accumulation (g)	Stem diameter (mm)	Chlorophyll content at 90 DAS
T ₁	194.52	12.33	146.83	16.42	34.48
T ₂	227.17	15.58	249.28	21.58	44.74
T ₃	219.16	14.25	214.91	20.22	40.82
T ₄	201.14	15.58	193.11	20.35	41.21
T ₅	201.87	16.08	244.04	20.8	40.37
T ₆	255.06	17.08	254.28	27.38	45.54
T ₇	199.95	14.25	182.37	19.89	35.68
T ₈	201.88	15.37	146.83	20.86	36.36
T ₉	199.6	13.50	146.83	20.97	38.17
T ₁₀	214.15	15.17	164.47	21.66	40.45
SEM (±)	0.15	0.46	1.72	1.15	0.36
C.D. (0.05%)	1.25	1.39	5.17	3.43	1.09

Details of treatments shown in materials and methods. *RDF (recommended dose of fertilizers); *NPK (IFFCO); *sources of inorganic fertilizers (Urea, DAP and MOP); *DAP -Di-ammonium phosphate; *MOP- Muriate of potash; *Significant at P≤0.05.

Table 2: Effect of different nutrients management on length of spike, No. of spikelet's per ear head, test weight, grain yield, Brix ration (%) and Juice extraction (%).

Tr. no.	Length ear head (cm)	No. of spikelet's per ear head	Grain yield (q ha ⁻¹)	Test weight (g)	Brix value (%)	Juice extraction (%)
T ₁	12.66	26.98	14.07	38.22	12.8	30.75
T ₂	16.33	41.44	30.12	43.44	18.70	47.45
T ₃	13.96	37.00	25.68	43.4	16.55	46.61
T ₄	13.66	34.55	23.98	46.37	16.08	46.86
T ₅	15.33	34.77	26.66	46.55	17.41	47.17
T ₆	18.44	42.993	30.87	55.13	19.9	50.45
T ₇	12.78	32.44	16.19	40.34	14.56	37.63
T ₈	12.88	31.98	16.45	42.55	14.04	37.32
T ₉	13.66	32.77	16.28	40.51	15.51	37.92
T ₁₀	14.66	39.88	17.59	41.93	16.6	39.41
SEM ±	0.36	0.86	0.44	1.10	0.81	0.52
C.D. (0.05%)	1.09	2.58	1.31	3.31	2.43	1.56

Details of treatments shown in materials and methods. *RDF (recommended dose of fertilizers); *NPK (IFFCO); *sources of inorganic fertilizers (Urea, DAP and MOP); *DAP -Di-ammonium phosphate; *MOP- Muriate of potash; *Significant at P≤0.05.

and bio-neema sufficient nutrient availability to support for optimal yield. These nutrient management strategies likely supply essential growth promoting nutrient for enable sweet sorghum achieve notable grain yield (Singh *et al.*, 2015). It is possible that the increased yield of sweet sorghum is due to the impact of nitrogen on plant metabolism, which boosts grain production and the function of zeolite in retaining nutrients and slowly releasing them in the root zone (Aslam *et al.*, 2021; Kuzin *et al.*, 2019.) The highest number of spikelets and longest ear head length achieved in sweet sorghum through the combined treatment application corresponds with the research results of Khaliq *et al.*, (2024). The addition of urea and zeolite together was found to significantly boost the 1000-grains weight, straw yield and grain yield compared to the control. Numerous experiments have documented the positive outcomes associated with the use of inorganic fertilizers combined with zeolite (Mondal *et al.*, 2021). The integration of inorganic fertilizers, organic amendments and zeolite could potentially lead to improved plant performance and increased yields (Sembiring *et al.*, 2017). Improved nutrient availability, enhanced water retention and a balanced nutrient composition can give rise to yield and productivity of sweet sorghum (Dubey *et al.*, 2019; Mehrab *et al.*, 2016).

Quality attributes

The maximum brix ratio (19.9%) and juice extraction percentage (50.45%) was observed under the T₆ (75% RDF + zeolite (1.5 t ha⁻¹) + Press-mud (15 t ha⁻¹) + Bio-neema (5 kg ha⁻¹), followed by T₂ (18.70% and 47.45%) and statically on par with T₅ (17.41% and 47.17%) and the lowest values of brix ratio (12.8%) and juice extraction percentage (30.75%) was recorded under their control treatments, which was representing 37.64% and 39.04% reduction compared to the superior yield quality (Table 2). It was probably due to organic + inorganic nutrient combination was providing essential nutrient for the development of plant to an enhanced photosynthesis rate, raised chlorophyll content and the hydrolysis of starch into soluble sugars collectively contributed to this effect (Holou and Stevens, 2012). The addition of inorganic matter and press-mud combined with zeolite enhanced the uptake of potassium, indicating the synergistic effects of zeolite and organic matter in increasing the availability of K for sweet sorghum and the nutrient use efficiency of this crop is greater than that of other cereals, this improvement in crop quality is aided by zeolite and organic matter in retaining nutrients in the root zone for plant use, as reported in Balm (2010).

CONCLUSION

Based on the experiment, sweet sorghum cultivation achieved superior growth, yield attributes, Brix ratio and juice extraction. Among the management practices, the application of 75% of the recommended dose of fertilizers

along with zeolite, press-mud and bio-neema resulted in significantly improved growth as well as yield parameters. These strategies not only enhance plant performance but also improve nutrient use efficiency, a crucial aspect of sustainable agricultural practices. The findings collectively indicate that advanced nutrient applications, integrating inorganic (chemical fertilizers) and organic (press-mud, bio-neema, Zeolite) sources, hold significant potential for sweet sorghum grower in the Indo-Gangetic region to achieve the highest yield and economical value.

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Disclaimers

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Conflict of interest

The authors declare there is no competing interest.

REFERENCES

- Addeo, N.F., Nocera, F.P., Toscanesi, M., Trifuoggi, M., Bovera, F., De Martino, L., De Prisco, R. (2023). On effect of poultry manure treatment with Effective Microorganisms with or without zeolite. *Environmental Science and Pollution Research*. 30(39): 91189-91198. <https://doi.org/10.1007/s11356-023-28793-2>
- Arumugam, R., Sivalingam, R., Perumal, C., Manivelu, R. (2025). Integrated nutrient management for enhanced maize yield and sustainability in Tamil Nadu, India. *Indian Journal of Agricultural Research*. 1-9. <https://doi.org/10.18805/IJARE.A-6247>.
- Ajeigbe, H.A., Akinseye, F.M., Ayuba, K., Jonah, J. (2018). Productivity and water use efficiency of sorghum [*Sorghum bicolor* (L.) moench] grown under different nitrogen applications in Sudan savanna zone, Nigeria. *International Journal of Agronomy*. 2018(1): 7676058. <https://doi.org/10.1155/2018/7676058>.
- Anbarasu, S., Ravichandran, M., Sriramachandrasekharan, M.V., Ganapathy, M. (2016). Effect of organic manures incorporation on electro kinetic properties and microbial dynamics in rice soil. *International Journal of Recent Scientific Research*. 7(7): 12349-12354.
- Aslam, M.A., Aziz, I., Shah, S.H., Muhammad, S., Latif, M., Khalid, A. (2021). Effects of biochar and zeolite integrated with nitrogen on soil characteristics, yield and quality of maize (*Zea mays* L.). *Pakistan Journal of Botany*. 53(6): 2047-2057. [http://dx.doi.org/10.30848/PJB2021-6\(27\)](http://dx.doi.org/10.30848/PJB2021-6(27)).

- Balm, M. (2010). The study on the effect of different levels of zeolite and water stress on growth, development and essential oil content of. *American Journal of Applied Sciences*. 7(1): 33-37.
- Dubey, A. and Mailapalli, D.R. (2019). Zeolite coated urea fertilizer using different binders: Fabrication, material properties and nitrogen release studies. *Environmental Technology and Innovation*. 16: 100452. <https://doi.org/10.1016/j.eti.2019.100452>.
- Holou, R.A. and Stevens, G. (2012). Juice, sugar and bagasse response of sweet sorghum [*Sorghum bicolor* (L.) Moench cv. M81E] to N fertilization and soil type. *Gcb Bioenergy*. 4(3): 302-310.
- Karimi, S., Majma, E. (2015). Effects of zeolite application on yield components and yield of sunflower grown under water deficit stress. *Crop Research*. 49(3): 23-29.
- Khalifa, T.H.H., Elsaka, M.S., Shabana, M.A., Abo-Elsooud, H.M. (2019). Effect of zeolite and mineral fertilizers on some soil properties and growth of Jew's mallow in clayey and sandy soils. *International Journal of Plant and Soil Science*. 3(12): 1-12.
- Khalique, A., Shehzad, M., Huma, M.K., Tahir, M.M., Javeed, H.M.R., Saeed, M.F., Mancinelli, R. (2024). Synergistic effects of urea, poultry manure and zeolite on wheat growth and yield. *Soil Systems*. 8(1): 18. <https://doi.org/10.3390/soilsystems8010018>.
- Kopittke, P.M., Lombi, E., Wang, P., Schjoerring, J.K., Husted, S. (2019). Nanomaterials as fertilizers for improving plant mineral nutrition and environmental outcomes. *Environmental Science: Nano*. 6(12): 3513-3524. <https://doi.org/10.1039/C9EN00971J>.
- Kuzin, E.N., Arefyev, A.N., Kuzina, E.E. (2019). Influence of municipal sewage sludge and their combinations with zeolite-containing agro-root on fertility of meadow-chernozem soil and productivity of grain-propagation crop rotation. *Vestnik of Ulyanovsk State Agricultural Academy*. (3): 47.
- Mehrab, N., Chorom, M., Hojati, S. (2016). Effect of raw and NH₄⁺-enriched zeolite on nitrogen uptake by wheat and nitrogen leaching in soils with different textures. *Communications in Soil Science and Plant Analysis*. 47(10): 1306-1316. <https://doi.org/10.1080/00103624.2016.1166377>.
- Mondal, M., Biswas, B., Garai, S., Sarkar, S., Banerjee, H., Brahmachari, K., Hossain, A. (2021). Zeolites enhance soil health, crop productivity and environmental safety. *Agronomy*. 11(3): 448. <https://doi.org/10.3390/agronomy11030448>.
- Namoobe, C., Nanwal, R. K., Kumar, P. (2014). Productivity and economics of sorghum varieties for grain as influenced by nitrogen levels in sandy loam soil. *International Journal of Natural Sciences Research*. 2(1): 5-11.
- Ozbahce, A., Tari, A.F., Gonulal, E., Simsekli, N. and Padem, H. (2015). The effect of zeolite applications on yield components and nutrient uptake of common bean under water stress. *Archives of Agronomy and Soil Science*. 61(5): 615-626. <https://doi.org/10.1080/03650340.2014.946021>.
- Ramesh, K., Reddy, K.S., Rashmi, I., Pankaj, U. (2010). Nanoporous zeolites as soil urease adsorbers: An opportunity for increasing nitrogen use efficiency. (In) *International Conference on Frontiers of Nanotechnology: Impact on India*. pp: 10.
- Roy, P., Basu, S., Chatterjee, J., Chakraborty, I., Dutta, R., Barik, S., Goswami, A. (2019). Management of low nitrogen input with potassium and phosphorus fertilizers for cropping system and yield of sweet sorghum crop [*Sorghum bicolor* (L.) Moench] in a field experiment at Panskura, East Midnapore, West Bengal. *Indian Journal of Agricultural Research*. 53(1): 73-77. doi: 10.18805/IJARE.A-5113.
- Sembiring, S., Sembiring, R., Karo, S. (2017). Zeolite and urea fertilizer in the growth and yield of maize. *Journal of Research in Agriculture and Animal Science*. 4(9): 14-24.
- Singh, N.J., Athokpam, H.S., Devi, K.N., Chongtham, N., Singh, N.B., Sharma, P.T., Dayananda, S. (2015). Effect of farm yard manure and press mud on fertility status of alkaline soil under maize-wheat cropping sequence. *African Journal of Agricultural Research*. 10(24): 2421-2431. <https://doi.org/10.5897/AJAR2013.8233>.
- Singh, U.K., Korav, S., Kumar, S. and Sujatha, HT. (2025). Influence of planting systems and nutrient management on maize growth, yield and light interception in a maize-soybean intercropping system. *Indian Journal of Agricultural Research*. 1-6. doi: 10.18805/IJARE.A-6286.
- Sodavadiya H.B., Patel V.J., Sadhu, A.C. (2023). Effect of integrated nutrient management on the growth and yield of chickpea (*Cicer arietinum* L.) under chickpea-forage sorghum (*Sorghum bicolor* L.) cropping sequence. *Legume Research*. 46(12): 1617-1622. doi: 10.18805/LR-4465.
- Umesh, S.K., Santhosh, K., Paramesh, V. and Biswajyoti, B. (2024). Impact of planting systems and nutrient management on growth and yield of maize and soybean in a maize + soybean cropping system. *Plant Science Today*. 11(4). <https://doi.org/10.14719/pst.4451>
- Zhang, X., Vesselinov, V.V. (2017). Integrated modeling approach for optimal management of water, energy and food security nexus. *Advances in Water Resources*. 10(1): 1-10. <https://doi.org/10.1016/j.advwatres.2016.12.017>.