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SOURCES OF GREENHOUSE GAS EMISSION IN AGRICULTURE AND ITS MITIGATION STRATEGIES-A REVIEW

Arati Ghatole*, B. J. Gawhale, and V. Rajagopal

ICAR-National Institute of Abiotic Stress Management, Malegaon (Kh.), Baramati-413115, Pune, MH, India

*Corresponding author email: aratighatole2016@gmail.com

ABSTRACT

Agriculture sectors considerably contribute 10-12 % of GHG emissions globally to the overall anthropogenic greenhouse gas emissions to the atmosphere. Depending on management, the agriculture sector can be both a source as well as net sink for carbon. This review explains the sources responsible for greenhouse gases emission in the agriculture sector and all the important strategies for lowering the greenhouse gas emission from agriculture like crop diversification, summer fallowing, tillage and irrigation management, N-use efficiency, soil carbon sequestration, bio-char application, organic farming, use of biofuel, livestock feed management and mitigation during rice cultivation etc. Utilizing these strategies can significantly reduce GHG emissions.

KEYWORDS Agriculture, Climate change, carbon footprint, CO_2 equivalent, Mitigation Strategies

INTRODUCTION

Global climate is rapidly changing, and for this, greenhouse gases are responsible; such gases are emitted by a variety of natural as well as anthropogenic sources. Greenhouse gases (GHG) act as a blanket around the planet, trapping the sun's heat and stopping it from escaping into space, resulting in Global Warming. Since the pre-industrial era, anthropogenic GHG emissions have contributed to significant increases carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) concentrations in the atmosphere (IPCC, 2014). Worldwide, the effects of climate change are already being felt in various ways, including changing weather patterns, melting ice caps, agricultural losses, altered precipitation patterns, more frequent and intense floods and droughts, and severe ecological imbalances. Additional negative impacts include substantial economic losses (Stern 2006). Agriculture is one of the sectors which is not only significantly affected by climate change and variability but is also directly responsible for 14 % of global greenhouse gas emissions. As the food demand increases with the rising population, the proportion of GHG emissions from the agricultural sector is also increasing. Numerous climate pollutants cause anthropogenic climate change, with CO_2, CH_4, and N_2O being the three main individuals responsible for global warming

(Myhre *et al.*, 2013). "The total amount of GHGs (measured in carbon equivalent (C-eq) released by all agricultural processes is known as the carbon footprint of agriculture".

The primary sources of GHG emission in agriculture include tillage, ploughing, irrigation, chemical fertilizer, Rice cultivation, crop residue burning, wet land, deforestation, manure management, raising livestock, and using associated machinery, which produces a significant amount of greenhouse gases. Therefore, for reducing greenhouse gas emissions the agricultural sector can play an important part. The practices such as summer fallowing, tillage management, irrigation management, organic farming, nitrogen use efficiency, efficient use of fossil fuel and other non-renewable energy sources, diversified cropping system, enhancing soil carbon sequestration, rice crop management, manure and other waste management, improved ruminant digestion efficiency etc., may help to reduce the GHG emissions from the agriculture sector.

SOURCES OF GHG IN AGRICULTURE

- *Tillage:* Tillage is one of the most important agricultural practices used to create suitable conditions for seedbed preparation and plant growth and is among the most important primary sources of CO_2 emission. Soil tillage increases soil microorganisms' respiration and CO_2 emissions from soil. As the tillage depth increases, CO_2 emission from soil significantly increases; therefore, it is assumed that CO_2 emission from soil decreases by reducing the depth of tillage (Reicosky and Archer 2007).
- *Rice cultivation:* Rice cultivation has been linked to GHG emission, namely methane (CH_4), and nitrous oxide (N_2O) (Babu *et al.*, 2005; Linquist *et al.*, 2012; Reiner *et al.*, 2000). Rice fields emit 32 to 44 Tg CH_4 yr^{-1} (Le Mer and Roger 2001). Due to the anaerobic characteristics of the soil, rice paddy contributes primarily to the CH_4 emission but also emits some N_2O when it floods (Pittelkow *et al.*, 2013). Due to CH_4 emissions contributing 45% of the total carbon footprint, rice has the highest carbon footprint per unit output, 1.60 kg CO_2-eq (Zhang *et al.*, (2017). Labile nitrogen and carbon concentrations rise in tropical low-land rice fields with high CO_2 and temperature, which is more responsible for CH_4 and N_2O emissions (Bhattacharya *et al.*, 2013).
- *Fertilizer Use:* One of the main sources of CO_2 and N_2O emissions is nitrogenous fertiliser. In total agricultural GHG emissions, synthetic fertilisers contribute 13% of all those (FAOSTAT 2014). When nitrogenous fertilizers are applied on soil a portion is being used in plant uptake while remaining portion is utilized by microorganisms for producing N_2O, and lost through leaching or volatilization process (IPCC, 2019). The main greenhouse gas (GHG) released during production is CO2, whereas the major field contribution is N_2O emission (Rao *et al.*, 2019).

- *Crop residue burning:* Burning straws both as fuel and on the field resulted in a significant loss of Carbon (Powlson *et al*., 2016). The carbon stored in residues is lost in the atmosphere as CO_2. 85 % of GHGs due to field burning of rice, wheat, and sugarcane residues (Sahai *et al*., 2011). In India, 488 million tonnes of crop residues were produced in 2017, and 24% were burned, emitting 211 Tg of CO2-e GHGs and other gaseous air pollutants (Ravindra *et al*., 2019).
- *Enteric fermentation:* Greenhouse gas (GHG) emissions from enteric fermentation consist of methane gas produced in the digestive systems of ruminants and, to a lesser extent, of non-ruminants. According to Hristov *et al.*, (2013), ruminant production produces 81% of the greenhouse gases (GHG) produced by the livestock industry, 90% of which come from rumen microbial methanogenesis (McAllister *et al.*, 2015). Compared to other ruminants or animals, beef and dairy cattle contribute more to the world's carbon footprint (Gerber *et al.*, 2013; Chhabra *et al.*, 2013).

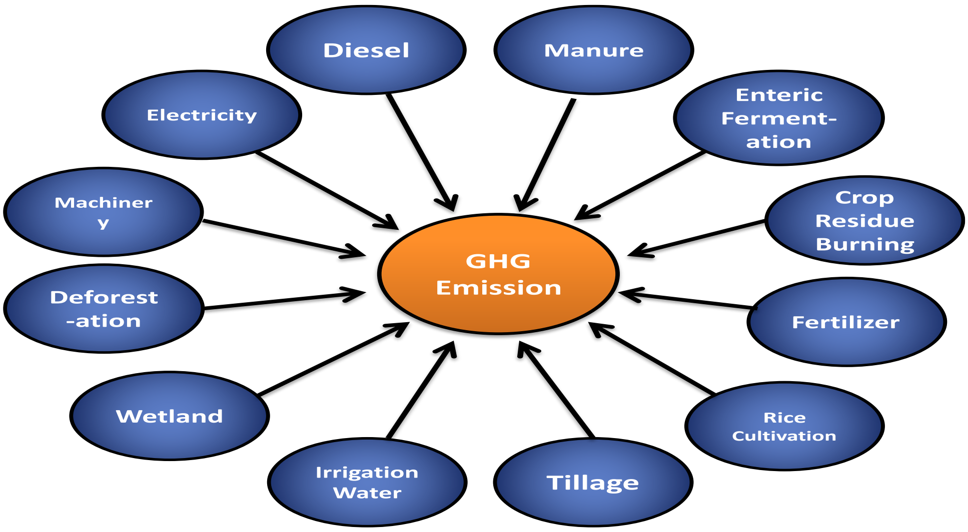

Fig 1. Sources of Green-House Gas Emission in Agriculture

- *Livestock Manure:* Manure contains organic matter and N, and as the organic matter decomposes, CH_4 and N_2O occur. Manure management in India accounts for 90 % of the total CH_4 emission (Chhabra *et al.*, 2013). The largest annual source of N_2O emissions in grasslands comes from animal faeces deposition (54%), followed by manure application (13%) and nitrogen fertilisers (7%) (Dangal *et al.*, 2019). Ruminant manure, of which 86% comes from cattle, is the source of 109 million tonnes of methane emissions to the atmosphere each year. The three main factors that affect the amount of CH_4 that manure exhales are the kind of storage, the climate, and the manure composition (Opio *et al.*, 2013).
- *Machinery:* Machinery is the major source of GHG emissions, as it uses energy in the form of fossil fuels. The greenhouse gas emissions of 160-200 kg CO_2-eq ha^{-1} from fuel consumption for field

operations for a non-irrigated corn-soybean-wheat rotation (Roberson *et al.*, 2000). In the cultivation of wheat and maize, machinery emissions from fuel use were 25% and 20%, respectively (Zhang *et al.*, 2017).

- *Diesel:* Diesel requires in the transport of fertilizers, pesticides, seeds, and other farm equipment, and major emissions occur during the tillage process. The diesel consumption depends upon the tractor's size, tillage depth, frequency, and type of tillage. In sunflower production, diesel consumption contributes to 12.24% of the carbon footprint (Yousefi *et al.*, 2017). Diesel contributed 6% and 19% to the total carbon footprint in mustard rice cultivation when using zero-tillage and conventional tillage systems (Yadav *et al.*, 2018).
- *Electricity:* The energy supply sector is the main global greenhouse gas (GHG) emission source. The second-largest contributor to greenhouse gas emissions is electric power. Approximately 60% of our electricity comes from burning fossil fuels, mostly coal and natural gas (USEIA 2019). Electricity used in agriculture contributed the most to carbon foot-printing (Yousefi *et al.*, 2017). In India, from 2000 to 2010, the emission from electricity use was 3% (Sah and Devakumar 2018).
- *Wetland:* wetlands are defined here as the land area that is either permanently or seasonally saturated, excluding small ponds, lakes, and coastal wetlands. Terrestrial wetlands are among the largest biogenic sources of methane, contributing to growing atmospheric CH_4 concentrations (Tian *et al.*, 2016). Wetland CH_4 emissions may, however, play a significant role in the atmospheric rise of methane due to the substantial reservoir of mineral and organic carbon held under anaerobic conditions. Furthermore, riparian wetlands emit more CO_2 to the atmosphere than CH_4 and N_2O because of higher plant and soil respiration (335-2790 mg m^2 h^{-1} in the wet season and 72-387 mg m^2 h^{-1} in the dry season) (Liu *et al.*, 2021).
- *Deforestation:* Deforestation is a significant contributor to climate change because plants absorb carbon dioxide (CO_2) from the atmosphere as they grow, and they store some of this carbon as aboveground and belowground biomass throughout their lifetime, when trees are burned, harvested, or otherwise die, they release their carbon back into the atmosphere. As estimated from 2015-2017 at global level, about 4.8 billion tonnes of carbon dioxide per year is lost due to deforestation of tropical forest (Annika Dean, 2019). In addition, forest land conversion to agriculture or pastures contributed 6-17 % of the world's total GHG emissions (IFOAM2016).
- *Irrigation water:* Irrigation is vital for achieving high crop yields in arid and semi-arid regions. However, irrigation is a very C-intensive process. According to Sloggett (1979), 23% of the energy required for agricultural production in the US was used for pumping on farms. Rainfed agriculture has

a lower carbon footprint than irrigated agriculture as the emission related to irrigation is reduced, and the areas are smaller, so the practices are done manually (Devakumar *et al.*, 2018).

MITIGATION STRATEGY

- *Crop diversification:* Crop diversity is growing multiple varieties of the same or distinct species of crops in a specific area through crop rotation and/or intercropping. Increased crop diversity increases productivity while reducing carbon emissions (Liu *et al.*, 2016). Due to the carbon and nitrogen sequestration in legume crops, they have a lower carbon footprint (Gan *et al.*, 2011). Crop diversification has been considered a vital cropping strategy for increasing agro-ecological produce and reducing greenhouse gas emissions. (Yang *et al.*, 2014; Minx *et al.*, 2009).
- *Summer fallowing:* The summer fallowing strategy lowers agriculture's carbon footprint by increasing nitrogen availability and decreasing the consumption of nitrogenous fertilizers. Additionally, summertime increases production (Liu *et al.*, 2016).
- *Enhancing soil C sequestration:* The most crucial method of lowering the quantity of GHGs in the atmosphere is soil carbon (C) sequestration. The SOC pool has a carbon content that is more than three times that of atmospheric CO_2: 1325 Pg C in the top 1 m and 3000 Pg C when assessments for deeper soil layers are considered (Kochy et.2015). Increased soil C sequestration can be achieved by keeping plant residues on the soil's surface, minimizing soil disturbance and erosion, using diversified cropping to create a continuous ground cover, and adding C-rich materials. (Lal and Follett, 2009). In addition, it is advised to use charcoal, mulch, cover crops, integrated nutrient management, conservation tillage, and diversified cropping systems to increase the SOC (Lal 2011).
- *Mitigation during rice cultivation:* Over half of the world's population relies primarily on rice as a food source. However, it is the main anthropogenic source of methane (CH_4) and nitrous oxide (N_2O). According to estimates, global CH_4 emissions comprise up to 19% of overall emissions, whereas rice fields are responsible for 11% of global agricultural N_2O emissions (IPCC, 2007). Because maize crops served as a weak sink for CH_4, switching rice with maize in a rotation lowered emissions. (Linquist et al. 2012). To lessen the high irrigation water requirement for paddy rice, the International Rice Research Institute (IRRI) has proposed a "safe alternate wetting and drying (AWD)" technology, which is also intended to reduce CH_4 emissions by 70%. (IRRI, 2013).

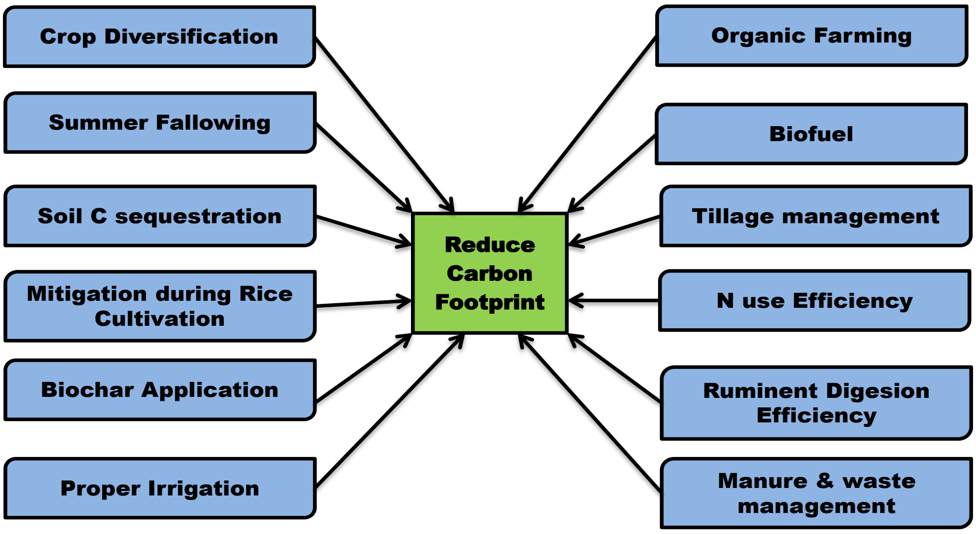

Fig 2: Mitigation measures to reduce GHG emission from agriculture

- *Bio-char application:* Bio-char is the solid product remaining after biomass is heated to temperatures typically between 300°C and 700°C under oxygen-deprived conditions, a process known as "pyrolysis. Biochar application has been widely reported to reduce N_2O emissions (Wu *et al.,* 2013; Cayuela *et al.,* 2013; Chang *et al.,* 2016; Hüppi *et al.,* 2016). Applying biochar to the soil has been shown to reduce denitrification and decrease N_2O emissions by 10-90%, indicating that biochar reduces N_2O emissions by facilitating the last step of the denitrification process and producing more N_2 rather than N_2O (Cayuela *et al.*, 2013).
- *Organic farming:* Organic farming uses less energy per unit area and yield than conventional techniques, lowering the environmental pollution. (Lynch *et al.*, 2012, Lee *et al.*, 2015). As a result, this approach is linked to less greenhouse gas (GHG) emissions and better soil carbon sequestration, making it an effective substitute for intensive farming in the face of climate change. According to Skinner *et al.*, (2019), organic farming can minimize N_2O emissions by 40.2%. Manure composting can reduce N2O emissions by 50% and CH_4 emissions by 70% in organic agriculture (IFOAM 2016).
- *Biofuel:* Fossil fuel usage makes a significant contribution to climate change. Due to their carbon neutrality, biofuels can reduce the amount of fossil fuels and the subsequent reduction in carbon dioxide emissions. Agricultural crops, along with their residues, can be considered as a source of fuel, either directly or after being transformed into fuels like ethanol or diesel. (Cannell 2003; Schneider and Mc Carl 2003). Burning crop leftovers that include lignin can also provide biofuel that minimizes overall emissions from electricity use (Liska *et al.*, 2014). By replacing electrical energy with solar-powered irrigation pumps, the agricultural carbon footprint decreased by 8.1%. Additionally, using machinery

driven by biofuels rather than diesel-powered equipment resulted in a 3.9% reduction in emissions during cotton cultivation. (Hedayati *et al.* 2019).

- *Tillage management:* Reduced tillage, minimum tillage, and non-inversion tillage are all terminology used to describe cultivation methods that do not use deep inversion ploughing and instead attempt to cultivate as minimally as possible, only to a depth of 15 cm. Tillage disturbs the soil, which tends to promote soil carbon losses through accelerated decomposition and erosion. (West & Post 2002; Gregorich et al. 2005). Crops left in a no-till situation after harvest enrich the soil with organic carbon (Powlson *et al.*, 2016; Nath *et al.*, 2017; Yadav *et al.*, 2018) and reduce the rate of oxidation of organic molecules due to soil cover (Lal 2004).
- *Improving N-use efficiency:* Crops don't always use nitrogen applied in fertilisers and manure effectively (Cassman *et al.*, 2003; Galloway *et al.*, 2003). Improving N use-efficiency can reduce N_2O emissions by soil microbes. Practices that improve N use efficiency include precision farming, slow-releasing fertilizer or nitrification inhibitors, right place and timing of N application (Dalal *et al.*, 2003; Monteny *et al.*, 2006). Several techniques, such as Green-Seeker and urea application based on leaf colour charts, make reducing emissions feasible by applying only the appropriate amount of fertilisers. For example, N_2O emissions in wheat farming systems can be reduced by 11-13% by adopting Green-seeker. (Nath *et al.*, 2017). The LCC-based urea application method boosts crop productivity and N use efficiency while reducing the emissions brought by fertiliser use. (Bhatia *et al.*, 2012).
- *Increasing ruminant digestion efficiency:* Methane (CH_4), a greenhouse gas that warms the globe and contributes to climate change, is released by cattle, sheep, and other ruminants. This methane is produced in the rumens of ruminants by the breakdown of cellulose by bacteria. It may be possible to reduce methane production by changing the rumen's fermentation process. Many variables, including cattle type, diet quality, and amount of feed consumed, affect methane emissions from ruminant animals. (Westberg *et al.*, 2001). Feeding extra concentrates, usually in place of forages, can lower methane emissions. (Blaxter & Clapperton 1965; Johnson & Johnson 1995; improved feeding practices (e.g., enhancing pasture quality), use of dietary amendments (e.g., edible oils, ionospheres (antibiotics), organic acids), and improved genetics (Kebreab *et al.*, 2006) and optimizing protein intake to reduce N excretion and N_2O emissions (Clark *et al.*, 2005).
- *Manure and other waste management:* During storage, animal manures can emit high quantities of N_2O and CH_4, although the actual amount of these emissions vary. Cooling or covering the sources or collecting the released CH_4 from the stored manure in tanks can reduce the emission (Clemens and Ahlgrimm 2001; Monteny *et al.*, 2006a; Monteny *et al.*, 2001b). Using CH_4 as fuel to produce on-site

power and heat energy, anaerobic digestion of manure results in the collection of biogases (CH_4, CO_2), improving industrial efficiencies (Kebreab *et al.*, 2006). Composting, covering stored manure, changing diet composition, adopting novel application techniques, and utilizing nitrification inhibitors are further options to lower GHG fluxes from manure (Kulling *et al.*, 2001).

- *Efficient irrigation method:* Eighteen per cent of the world's croplands now receive supplementary water through irrigation (Millennium Ecosystem Assessment 2005). Efficient water utilisation for crop growth will be essential in adapting to global climate change. However, irrigated agriculture is a major problem due to its high economic value comparative to rain-fed agriculture systems, significant output potential, and vulnerability to water supply constraints (Hatfield *et al.*, 2011). Adopting conservation measures that increase water storage and lowers evaporative demand is one of the methods for efficient water usage (Follett, 2012).

CONCLUSION

Various agricultural production processes and inputs share the major significant proportion of greenhouse gas emissions and climate change, and climate change can be mitigated by preventing the emission from multiple agricultural sources and reducing the current greenhouse gas level back to the pre-industrial revolution. Still, for this, no single option is sufficient by itself, a combination of various green-house gas offsetting strategies like crop diversification, summer fallowing, tillage and irrigation management, Fertilizer and manure management, bio-char application, soil carbon sequestration, organic farming, use of biofuel, improved ruminant feed efficiency, and mitigation during rice cultivation etc. can help reduce the carbon footprint of agriculture sector.

REFERENCES

Annika, Dean, 2019. Deforestation and climate change, climate council of Australia.

Babu, Y., Jagadeesh, L., Frolking, C., Nayak, S., Datta, D.R. and Adhya, T.K. 2005. Modelling of methane emissions from rice-based production systems in India with the denitrification and decomposition model. *Field Valid. Sensit. Anal.* 89, 1904-1912.

Bhatia, A., Pathak H., Jain N., Singh, P.K. and Tomer, R., 2012. Greenhouse gas mitigation in rice-wheat system with leaf color chart-based urea application. *Environ Monit Assess.* 184 (5): 3095-3107.

Bhattacharyya, P., Roy, K.S., Neogi, S., Dash P.K., Nayak, A.K., Mahonty, S., Baig, M.J., Sarkar, P.K., Rao, K.S., 2013. Impact of elevated CO_2 and temperature on soil C and N dynamics in relation to CH4 and N_2O emissions from tropical flooded rice (*Oryza sativa L.*). *Sci Total Environ.* 461-462: 601-611.

Blaxter, K.L. and Clapperton, J.L., 1965. Prediction of the amount of methane produced by ruminants. *Br. J. Nutr*. 19, 511-522.

Cannell, M. G. R., 2003. Carbon sequestration and biomass energy offset: theoretical, potential and achievable capacities globally, in Europe and the UK. *Biomass Bioenergy*. 24, 97-116.

Cassman, K.G., Dobermann, A., Walters, D.T. and Yang, H., 2003. Meeting cereal demand while protecting natural resources and improving environmental quality. *Annu. Rev. Environ. Resour*. 28, 315-358.

Cayuela, M.L., Sanchez-Monedero, M.A., Roig, A., Hanley, K., Enders, A., Lehmann, J., 2013. Biochar and denitrification in soils when, how much and why does biochar reduce N_2O emissions? *Sci Rep*. 3:1732.

Chang, J.Y., Clay, D.E., Clay, S.A., Chintala, R., Miller, J.M., Schumacher, T., 2016. Biochar reduced nitrous oxide and carbon dioxide emissions from soil with different water and temperature cycles. *Agron J*. 108: 2214-2221.

Chhabra, A., Manjunath, K.R., Panigrahy, S., Parihar, J.S., 2013. Greenhouse gas emissions from Indian livestock. *Clim. Change*. 117 (1-2): 329-34.

Clark, H., Pinares, C. and de Klein, C., 2005. Methane and nitrous oxide emissions from grazed grasslands. In Grassland a global resource (ed. D. McGilloway), pp. 279-293.

Clemens, J. and Ahlgrimm, H.J., 2001. Greenhouse gases from animal husbandry: mitigation options. *Nutr. Cycl. Agroecosyst.* 60, 287-300.

Dalal, R.C., Wang, W., Robertson, G.P. and Parton, W.J., 2003. Nitrous oxide emission from Australian agricultural lands and mitigation options: a review. *Aust. J. Soil Res.* 41, 165-195.

Dangal, S.R.S., Tian, H., Xu, R., Chang, J., Canadell, J.G., Ciais, P., 2019. Global nitrous oxide emission from pasturelands and rangelands: magnitude, spatiotemporal patterns, and attribution. *Glob. Biogeochem Cy*. 33, 200-222.

Delgado, J.A., Groffman, P.M., Nearing, M.A., Goddard, T., Reicosky, D., Lal, R., Kitchen, N.R., Rice, C.W., Towery, D., Salon, P., (2011). Conservation practices to mitigate and adapt to climate change. *J. Soil Water Conserv*. 66 (4), 118Ae129A.

Devakumar, A.S., Pardis, R. and Manjunath, V., 2018. Carbon footprint of crop cultivation process under semiarid conditions. *Agric Res.* 7 (2): 167-175.

FAOSTAT, 2014. Food and agriculture organization of the United Nations http://www.fao.org/3/ a-i3671e.pdf.

Follett, R.F., 2012. Beyond mitigation: adaptation of agricultural strategies to overcome projected climate change. In: Liebig, M.A., Franzluebbers, A.J., Follett, R.F. (Eds.), Managing agricultural Greenhouse Gases: Coordinated Agricultural Research through GRACE net to Address Our Changing Climate. Academic Press, San Diego, CA.

Galloway, J.N., Aber, J.D., Erisman, J.W., Seitzinger, S.P., Howarth, R.W., Cowling, E.B. and Cosby, B.J., 2003. *The nitrogen cascade. Bioscience*. 53, 341-356.

Gan, Y., Liang, C., Hamel, C., Cutforth, H., Wang, H., 2011. Strategies for reducing the carbon footprint of field crops for semiarid areas. *A Rev Agron Sustain Dev*. 31 (4): 643-656.

Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. and Tempio, G., 2013. Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities. Food and Agriculture Organization of the United Nations.

Gregorich, E.G., Rochette, P., Vanden Bygaart, A.J. and Angers, D.A., 2005. Greenhouse gas contributions of agricultural soils and potential mitigation practices in eastern Canada. *Soil Till. Res*. 83, 53-72.

Hatfield, J.L., Boote, K.J., Kimball, B.A., Ziska, L.H., Izaurralde, R.C., Ort, D., Thompson, A.M. and Wolfe, D., 2011. Climate impacts on agriculture: implications for crop production. *Agron. J*. 103, 351e370.

Hedayati, M., Brock, P.M., Nachimuthu, G. and Schwenke, G., 2019. Farm-level strategies to reduce the life cycle greenhouse gas emissions of cotton production: *An Australian perspective. J Clean Prod*. 212: 974-985.

Hristov, A.N., Oh, J., Lee, C., Meinen, R., Montes, F. and Ott, F., 2013. Mitigation of greenhouse gas emissions in livestock production. In: Gerber PJ, Henderson B, Makkar HPS, editors. A review of options for non-CO2 emissions. Rome: FAO; 226.

Hüppi, R., Neftel, A., Lehmann, M.F., Krauss, M., Six, J. and Leifeld, J., 2016. N use efficiencies and N2O emissions in two contrasting, biochar amended soils under winter wheat-cover crop-sorghum rotation. *Environ Res Lett*. 11: 084013.

IFOAM report, 2016. https://www.organicseurope.bio/content/uploads/2020/06/ifoameu_advocacy_climate_change_report_2016.pdf.

International Rice Research Institute, 2013. Smart water technique for rice. Available at http://eiard.org/media/uploads/File/Case%20studies/2013_SDC%20funded/IRRI%20%20Smart%20water%20technique%20for%20rice

IPCC, 2007. Climate Change (2007): Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In: Core Writing Team, Pachauri, R.K, Reisinger, A. (Eds.), IPCC, Geneva, Switzerland.

IPCC, 2014. Climate Change. Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, pp. 151.

IPCC. 2019. Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems, Summary for Policymakers.

Johnson, K. A. & Johnson, D. E. (1995). Methane emissions from cattle. J. Anim. Sci. 73, 2483–2492.

Kebreab, E., Clark, K., Wagner-Riddle, C., France, J., (2006). Methane and nitrous oxide emissions from animal agriculture: a review. Can. J. Anim. Sci. 86, 135e158.

Kochy, M., Hiederer, R. and Freibauer, A., 2015. Global distribution of soil organic carbon-Part 1: masses and frequency distributions of SOC stocks for the tropics, permafrost regions, wet-lands, and the world. *Soil*. 1: 351-365.

Kulling, D.R., Henzi, H.K., Krober, T.F., Neftel, A., Sutter, F., Lischer, P. and Kreuzer, M., 2001. Emissions of ammonia, nitrous oxide and methane from different types of dairy manure during storage as affected by dietary protein content. *J. Agric. Sci.* 137, 235e250.

Lal, R. and Follett, R.F., 2009. Soils and climate change. In: Lal, R., Follett, R.F. (Eds.), Soil Carbon Sequestration and the Greenhouse Effect, second ed.). SSSA Spec. Publ. 57. ASA-CSSA-SSSA, Madison, WI, pp. xxiexxviii.

Lal, R., 2004. Carbon emission from farm operations. Environ Int 30 (7): 981-990.

Lal, R., 2011. Sequestering carbon in soils of agro-ecosystems. *Food Policy*. 36: S33-S39.

Le Mer, J.L. and Roger, P., 2001. Production, oxidation, emission and consumption of methane by soils: a review. *Eur J Soil Biol.* 37: 25-50.

Lee, K.S., Choe, Y.C. and Park, S.H., 2015. Measuring the environmental effects of organic farming: A meta-analysis of structural variables in empirical research. *Journal of Environmental Management*. 162, 263-274.

Linquist, B., Van Groenigen, K.J., Adviento-Borbe, M.A., Pittelkow, C. and Van Kessel, C., 2012. An agronomic assessment of greenhouse gas emissions from major cereal crops. Glob Change Biol 18 (1): 194-209.

Liska, A.J., Yang, H., Milner, M., Goddard, S., Blanco-Canqui, H., Pelton, M.P., Fang, S.S., Zhu, H. and Suyker, A.E., 2014. Biofuels from crop residue can reduce soil carbon and increase CO2 emissions. Nat Clim Chang 4 (5): 398.

Liu, C., Cutforth, H., Chai, Q. and Gan, Y., 2016. Farming tactics to reduce the carbon footprint of crop cultivation in semiarid areas. *A Rev Agron Sustain Dev*. 36 (4): 69.

Liu, X., Lu, X., Yu, R., Sun, H., Xue, H., Qi, Z., Cao, Z., Zhang, Z. and Liu, T., 2021. Greenhouse gases emissions from riparian wetlands: an example from the Inner Mongolia grassland region in China, *Bio-geosciences*. 18, 4855-4872.

Lynch, D.H., Halberg, N. and Bhatta, G.D., 2012. Environmental impact of organic agriculture in temperate regions. CAB Review, 7, 10.

McAllister, T.A., Meale, S.J., Valle, E., Guan, L.L., Zhou, M. and Kelly, W.J., 2015. Use of genomics and transcriptomics to identify strategies to lower ruminal methanogenesis. *J Anim Sci*. 93: 1431- 49.

Millennium Ecosystem Assessment 2005 Findings from the conditions and trend working group. Washington, DC: Island Press

Minx, J.C., Wiedmann, T., Wood, R., Peters, G.P., Lenzen, M., Owen, A., Scott, K., Barrett, j., Hubacek, K., Baiocchi, G., Paul, A., Dawkins, E., Briggs, J., Guan, D., Suh, S., Ackerman, F., 2009. Input-output analysis and carbon footprinting: an overview of applications. *Econ syst Res* 21: 187-216.

Monteny, G.J., Bannink, A. and Chadwick, D., 2006a. Greenhouse gas abatement strategies for animal husbandry. *Agric. Ecosyst. Environ*. 112, 163-170.

Monteny, G.J., Groenestein, C.M. and Hilhorst, M.A., 2001b. Interactions and coupling between emissions of methane and nitrous oxide from animal husbandry. *Nutr. Cycl. Agroecosyst.* 60, 123-132.

Myhre, G., Shindell, D., Breon, F.-M., Collins, W., Fuglestvedt, J. and Huang, D., 2013. “Anthropogenic and natural radiative forcing,” in Climate Change. *The Physical Science Basis*. 659-740.

Nath, C.P., Das, T.K., Rana, K.S., Bhattacharyya, R., Pathak, H., Paul, S., Meena, M.C. and Singh, S.B., 2017. Greenhouse gases emission, soil organic carbon and wheat yield as affected by tillage systems and nitrogen management practices. *Arch Agron Soil Sci*. 63 (12): 1644-1660.

Opio, C., Gerber, P., Mottet, A., Falcucci, A., Tempio, G., MacLeod, M., Vellinga, T., Henderson, B. and Steinfeld, H., 2013. Greenhouse Gas Emissions from Ruminant Supply, 688 Chains-A Global Life Cycle Assessment. Food and Agriculture Organization of the 689 United Nations (FAO), Rome.

Pittelkow, C.M., Adviento-Borbe, M.A., Hill, J.E., Six, J., Van Kessel, C. and Linquist, B.A., 2013. Yield–scaled global warming potential of annual nitrous oxide and methane emissions from continuously flooded rice in response to nitrogen input. *Agric Ecosyst Environ*. 177: 10-20.

Powlson, D.S., Stirling, C.M., Thierfelder, C., White, R.P. and Jat, M.L., 2016. Does conservation agriculture deliver climate change mitigation through soil carbon sequestration in tropical agro-ecosystems? *Agric Ecosyst Environ* 220: 164-174.

Rao, N.D., Poblete-Cazenave, M., Bhalerao, R., Davis, K.F. and Parkinson, S., 2019. Spatial analysis of energy use and GHG emissions from cereal production in India. *Sci Total Environ*. 654: 841-849.

Ravindra, K., Singh, T. and Mor, S., 2019. Emissions of air pollutants from primary crop residue burning in India and their mitigation strategies for cleaner emissions. *J Clean Prod*. 208: 261-273.

Reicosky, D.C. and Archer, D.W., 2007. Moldboard plow tillage depth and short-term carbon dioxide release. *Soil Tillage Res*. 94 (1): 109-121.

Reiner, W. and Milkha, S.A., 2000. The role of rice plants in regulating mechanisms of methane missions. *Biol. Fertil. Soils*. 31, 20-29.

Robertson, E.A.P. and Harwood, R.R., 2000. Greenhouse gases in intensive agriculture: contributions of individual gases to the radiative forcing of the atmosphere. *Science*. 289, 1922-1925.

Sah, D. and Devakumar, A.S., 2018. The carbon footprint of agricultural crop cultivation in India. *Carbon Manag*. 9 (3): 213-225.

Sahai, S., Sharma, C., Singh, S.K. and Gupta, P.K., 2011. Assessment of trace gases, carbon and nitrogen emissions from field burning of agricultural residues in India. *Nutr Cycl Agroecosyst* 89 (2): 143-157.

Schneider, U.A. and Mc Carl, B.A., 2003. Economic potential of biomass-based fuels for greenhouse gas emission mitigation. *Environ. Resour. Econ*. 24, 291-312.

Skinner, C., Gattinger, A., Krauss, M., Krause, H.M., Mayer, J., Van der Heijden, M.G. and Mader, P., 2019. The impact of long-term organic farming on soil-derived greenhouse gas emissions. *Sci Rep*. 9 (1): 1702.

Sloggett, G., 1979. Energy use and U.S. agriculture: irrigation pumping 1974-1977. *Agric Economic Report* #436. Washington (DC): USDA.

Stern, N., 2006. Stern review: the economics of climate change. Cambridge University Press, Cambridge.

Tian, H., 2016. The terrestrial biosphere as a net source of greenhouse gases to the atmosphere. *Nature*. 531, 225-228.

U.S. Energy Information Administration, 2019. *Electricity Explained-Basics*.

West, T.O. and Post, W.M., 2002. Soil organic carbon sequestration rates by tillage and crop rotation: a global data analysis. *Soil Sci. Soc. Am. J*. 66, 1930-1946.

Westberg, H., Lamb, B., Johnson, K.A. and Huyler, M., 2001. Inventory of methane emissions from U.S. cattle. *J. Geophys. Res*. 106 (12), 12633e12642.

Wu, F.P., Jia, Z.K., Wang, S.G., Chang, S.X. and Startsev, A., 2013. Contrasting effects of wheat straw and its biochar on greenhouse gas emissions and enzyme activities in a Chernozemic soil. *Biol Fert Soils*. 49: 555-565.

Yadav, G.S., Das, A., Lal, R., Babu, S., Meena, R.S., Saha, P., Singh, R. and Datta, M., 2018. Energy budget and carbon footprint in a no-till and mulch-based rice-mustard cropping system. *J Clean Prod*. 191: 144-157.

Yang, X., Gao, W., Zhang, M., Chen, Y. and Sui, P., 2014. Reducing agricultural carbon footprint through diversified crop rotation systems in the North China Plain. *J Clean Prod*. 76: 131-139. https://doi.org/10.1016/j.jclepro.2014.03.063

Yousefi, M., Khoramivafa, M. and Damghani, A.M., 2017. Water footprint and carbon footprint of the energy consumption in sunflower agroecosystems. *Environ Sci Pollut Res*. 24 (24): 19827-19834.

Zhang, Z., Zimmermann, N., Stenke, A., Hodson, E., Zhu, G., Haung, C. and Poulter, B., 2017. Emerging role of wetland methane emission in driving 21st century climate change. Proceeding of *National Academy of Sciences*. 114 (36), 9647-9652.

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CHICKPEA: A PLANT-BASED NUTRIENT SOURCE

Nimmy M.S.[1], Ramawatar Nagar[1], Billeswar Mohanta[1], Sandhya Sharma[1] and Vinod Kumar[2]

[1]ICAR - National Institute for Plant Biotechnology, New Delhi -110012

[2]Department of molecular biology and genetic engineering, Bihar Agricultural University, Sabour, Bhagalpur, Bihar - 813210

*Corresponding author email: biotech.vinod@gmail.com

ABSTRACT

Chickpea is a nutrient-rich pulse crop having 40-60% digestible carbohydrates, 15-22% protein, 4-8% essential fats and a range of minerals and vitamins. One of the best reasons for choosing chickpeas as a staple food is they can be consumed from their early stage of growth, like when they are green (immature chickpea seeds). Green chickpea seeds are used as a vegetable. Value-added food products can be derived from chickpeas as a base ingredient for making another secondary food item.

INTRODUCTION

Chickpea (*Cicer arietinum L.*), commonly known as Bengal gram, is an important pulse crop cultivated since immemorial. Its nutritional use dates back to ancient times; even in Ayurvedic medicine, chickpea is mentioned. It is a good source of carbohydrates (50–58%), protein (15–22%), fat (3.8–10.20%), and micronutrients (<1%; USDA, 2021). It also contains dietary fibres, vitamins, minerals and many potentially beneficial phytochemicals that help us keep healthy. A 100-gram serving of chickpea contains 20 % or more of the daily value (DV) for protein, dietary fibre, folate, and several minerals like iron and phosphorus. High protein content, dietary fibre, antioxidant properties, anti-inflammatory activities, low glycaemic index, and various physiological effects beneficial for human health on a low budget make chickpeas a potential functional food and nutraceutical. (Yust *et al.*, 2012). The nutritional deficiency created a high demand for chickpea in present times.

CHICKPEA AS A SOURCE OF PROTEIN

Being a pulse crop, chickpea is a key source of protein and hence is the most consumed legume in the world. Its crude protein content is reported to range from 12.6 to 30.5 per cent. The protein quality in chickpeas is better than other pulses (Singh,1985). The protein concentration of desi chickpea seed is 16.7%-30.6%, and the protein concentration of Kabuli chickpea seed is 12.6%-29.0%, which is 2 to 3 times higher than other cereal grains. It is also reported that the seeds of chickpea provide a primary source of dietary proteins associated with health-promoting benefits in foremost diseases like diabetes, cardiovascular diseases and some cancers (Roy *et al.*, 2010). Chickpea proteins are considered plant-based and more sustainable and healthy than those derived from animals. Chickpea protein is rich in essential amino acids such as isoleucine, lysine, total aromatic amino acids and tryptophan (Alajaji & El-Adawy, 2006).

CHICKPEA AS A SOURCE OF VITAMINS AND MINERALS

According to WHO, daily consumption of 100gm chickpea can fulfil the daily requirement of iron and zinc. Chickpea also contains folic acid, tocopherols, and vitamin B complex (B2, B5, and B6) (Jukanti *et al.*, 2012). In addition, the vitamin A precursor Beta-carotene is also a significant source of other carotenoids, including canthaxanthin and xanthophyll (Thavarajah and Thavarajah, 2012).

A Pics of chickpea grown in field and its seed after harvesting

CHICKPEA AS A SOURCE OF ESSENTIAL FATTY ACIDS

The fatty acid composition of the chickpea seed is important because fats govern the texture, shelf-life, flavour, aroma, and nutritional composition of chickpea-based food products. It is a non-oilseed crop with a higher fat content than other pulse crops. Sterols, tocopherols and lipids are components of fat found in chickpea (Jukanti *et al.*, 2012). It contains a very small amount of lipids, mostly made up of unsaturated fats such as linoleic acids and oleic acids. For this reason, it is very effective for heart patients. The lipid concentration of desi chickpea seed is 2.9%-7.4%, and the lipid concentration of Kabuli chickpea seed is 3.4%-8.8% (where a maximum of this lipid is made up of unsaturated fat in both types of chickpeas) (Wood & Grusak, 2007).

CHICKPEA AS A SOURCE OF CARBOHYDRATES

Other macro molecules like carbohydrates are also present in chickpea seeds. The carbohydrate range in the Desi variety of chickpeas is 51-65%, and for the Kabuli variety of chickpeas is 54-71%. The starch content by weight in chickpeas is 30-57%. In the desi variety of chickpea, the amylase content is 20-42%; for the Kabuli variety of chickpeas, the amylase content is 21.0 - 46.5%. Because of the high amount of amylase, the stored form of carbohydrates in chickpea is hard to digest, and that's why roasted chickpeas are best for starch consumption (Rathore *et al.*, 2021). In addition, due to high amylose content and resistant starch, chickpeas have a low glycaemic index; as a result, their seeds show anti-diabetic activities.

CONCLUSION

Chickpea is a nutrient-rich pulse crop having 40-60% digestible carbohydrates, 15-22% protein, 4-8% essential fats and a range of minerals and vitamins. One of the best reasons for choosing chickpeas as a staple food is they can be consumed from their early stage of growth, like when they are green (immature chickpea seeds). Green chickpea seeds are used as a vegetable. Value-added food products can be derived from chickpeas as a base ingredient for making another secondary food item. (Kaur & Prasad, 2021) Many postmenopausal women have suffered from obesity and insulin resistance due to the decline of estrogen. The use of chickpeas may result in the prevention of type 2 diabetes and obesity. The overall total phenolic contents of chickpeas are higher than soybeans.

REFERENCES

Alajaji, S.A., and El-Adawy, T.A. 2006. Nutritional composition of chickpea (Cicer arietinum L.) as affected by microwave cooking and other traditional cooking methods. *Journal of Food Composition and Analysis* 19: 806–812.

Choi, J. S., Koh, I. U., and Song, J. 2012. Genistein reduced insulin resistance index through modulating lipid metabolism in ovariectomized rats. *Nutrition Research*, 32(11): 844-855.

Jukanti, A. K., Gaur, P. M., Gowda, C. L. L., and Chibbar, R. N. 2012. Nutritional quality and health benefits of chickpea (Cicer arietinum L.): a review. *British Journal of Nutrition*, *108*(S1): S11-S26.

Kaur, R., and Prasad, K. 2021. Technological, processing and nutritional aspects of chickpea (Cicer arietinum)-A review. *Trends in Food Science & Technology*, 109: 448-463.

Rathore, M., Prakash, H. G., and Bala, S. 2021. Evaluation of the Nutritional quality and health benefits of chickpea (Cicer arietinum L.) by using new technology in agriculture (Near Infra-red spectroscopy-2500). *Asian Journal of Dairy and Food Research*, 40(1): 123-126.

Roy, F., Boye, I.J., and Simpson, B.K. 2010. Bioactive proteins and peptides in pulse crops: pea, chickpea and lentil. *Food Research International* 43: 432–442.

Singh, U. 1985. Nutritional quality of chickpea (*Cicer arietinum* L.): current status and future research needs. *Plant Foods Human Nutrition* 35: 339–351

USDA 2021. https://fdc.nal.usda.gov/fdc-app.html#/food-details/174288/ nutrients (Accessed August 30, 2021).

Wood, J. A., and Grusak, M. A. 2007. Nutritional value of chickpea. In *Chickpea breeding and management* (pp. 101-142). Wallingford UK: CABI.

Yust, M. D. M., Millán-Linares, M. D. C., Alcaide-Hidalgo, J. M., Millán, F., and Pedroche, J. 2012. Hypocholesterolaemic and antioxidant activities of chickpea (Cicer arietinum L.) protein hydrolysates. *Journal of the Science of Food and Agriculture*, *92*(9): 1994-2001.

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UTILIZATION OF WHEY: ENVIRONMENTALLY FRIENDLY USES

Soniya Ashok Ranveer

Dairy Microbiology Division, ICAR-National Dairy Research Institute, Karnal, Haryana

Corresponding author email: soniyaranveer11@gmail.com

ABSTRACT

The high organic matter concentration of the whey produced as a by- or co-product by the dairy industry has caused serious environmental issues. Over the past few decades, researchers have looked into ways to make better use of whey, turning it from a waste product into a useful raw ingredient. Developing whey powders, whey proteins, functional food and drinks, edible films and coatings, lactic acid and other biochemicals, bioplastic, biofuels, and related important bioproducts is a primary focus of sustainable whey management. Sustainable whey use is discussed in this study, along with new refining methodologies and integrated processes for transforming whey, lactose, and whey proteins into high-value-added whey-based products.

INTRODUCTION

Large quantities of by-products, primarily whey, are produced due to the expanding dairy sector. Due to its potency as an organic effluent, cheese whey can harm the environment if not handled correctly. Cheese whey has a COD that can go anywhere from 50 to 80 g L^{-1} and a BOD that can be anywhere from 40 to 60 g L^{-1}. The bulk of the organic burden is made up of lactose, fat, and protein. A considerable volume of whey is disposed of as wastewater, and this practise is linked to serious environmental concerns; without sustainable measures, whey is considered the most important environmental pollutant of the dairy sector. Whey management should be geared toward a cost-effective and sustainable method of utilisation and towards the manufacture of novel, useful goods to make use of the nutritious content of whey while simultaneously mitigating the adverse consequences of disposal in the environment. This research aims to find and benefit from the reuse of dairy waste and by-products, with a particular focus on the sustainable use of whey, as well as lactose and proteins from whey, to make high-value-added products (Çelik *et al.*, 2016). Sustainable whey management is outlined, together with the most up-to-date research and developments in refining technology, and best practises for minimising the industry's environmental impact are discussed (Gadhe *et al.*, 2015).

COMPOSITION OF WHEY AND POTENTIAL BENEFITS

The watery, yellow-green portion of milk (serum) that is left over after the curd is separated during the cheese-making process is known as whey. About 85–90% of milk's volume is made up of it, and it comprises 55% of the nutrients found in milk. The average composition of dry whey residue is as follows: 70% lactose (depending on how acidic the whey is), 14% proteins, 9% minerals, 4% lipids, and 3% lactic acid (Jambrak *et al*., 2018). It is divided into sour and sweet whey, depending on how the milk protein coagulates. The remaining whey is converted into sweet whey powder, demineralized whey, de-lactose whey, whey protein concentrate (WPC), whey protein isolate (WPI), or lactose. Sour whey with a pH whey powder (Çelik *et al*., 2016).

A pic of whey protein

USE OF WHEY AND ITS COMPONENTS IN A SUSTAINABLE MANNER

In order to reduce the environmental impact of whey disposal and the high operational costs of whey processing, new sustainable techniques of whey utilisation must be looked for as the dairy sector records continual growth in the volume of generated whey. In order to apply sustainable whey management, it is important to have a deeper understanding of how goods and services influence society and the environment over their useful lives and how their consumption affects them (Gadhe *et al*., 2015). There are numerous approaches to sustainable whey management, most of which focus on biotechnological and gastronomic applications for the creation of value-added products such lactic acid, bioethanol, bioplastics, biogas, etc. whey powder, and functional meals and beverages. While whey in large quantities can be converted to bioethanol, whey in smaller amounts is best used to make fermented or unfermented beverages. In this manner, sustainable whey management could help to meet some initial requirements, such as clean water and sanitation, industry: innovation and infrastructure, responsible consumption and production, and its subgoals: improving water quality, enhancing the sustainability of the infrastructure, mitigating global food waste and food losses, and decreasing waste generation. Making whey into useful raw material and then processing it further to create high-value goods can help limit the number of dangerous compounds released into the environment and lessen environmental pollution (Çelik *et al*., 2016). Additionally, it might reduce the amount of untreated wastewater by half and significantly boost worldwide recycling and safe reuse. Additionally, resource efficiency would be improved, clean, environmentally friendly industrial techniques would be used, and the amount of food lost globally per person in manufacturing and supply chains would be cut in half.

PROCESSING OF LIQUID WHEY

Whey powders: One of the most common methods to use liquid whey is to make whey powders. Even though 70% of yearly whey processing involves drying, new technologies have prompted the investigation of other methods for turning whey into significant value-added products (Gadhe *et al*., 2015). Whey powder manufacture often includes numerous steps, including A) whey clearing, B) cream separation and pasteurisation, C) evaporation-based concentration of total solids (40-60 %), D) lactose crystallisation and E) spray-dried whey drying (removal of water from whey) (Çelik *et al*., 2016).

Functional foods and beverages: Functional foods and beverages are one of the most ambitious and novel food categories. They continue to attract the curiosity of many consumers since they provide health advantages beyond basic nutrition (Zandona *et al*., 2021). Whey and its components are becoming more popular as functional ingredients in dietary and health products, whilst bioactive proteins are becoming more popular in the pharmaceutical and nutritional industries. Until now, researchers have concentrated on manufacturing whey-based beverages from either native sweet and sour whey or powdered, deproteinised, and thinned whey. The world's leading dairy businesses have launched a new generation of whey-based products. The production of such beverages is proving to be the most cost-effective method for using whey in human nutrition. Still, there are several challenges involved in doing so, including the high-water content's susceptibility to microscopic microbial spoilage and the sensitivity of whey proteins to heat treatments at temperatures above 60°C (Çelik *et al*., 2016). After the typical heat treatment of whey (at 72 °C for 15-20 s), most whey proteins precipitate. In order to produce whey beverages, significant research is focused on using non-thermal methods such as membrane separation, high-intensity ultrasound, or supercritical CO2 technology.

Biogas: Due to the increased environmental regulations, fermentation techniques are now a widely used alternative to traditional methods for treating agro-industrial leftovers. Additionally, the digestion of garbage yields biogas that can be utilised to generate electricity, providing both environmental and financial advantages (Jambrak *et al*., 2018). Whey should be combined with other forms of waste or manure to boost productivity because anaerobic digestion results in rapid acid evolution and low biogas production due to its high organic content and low buffer capacity. The enormous energy potential of the biogas created when cheese whey is digested utilising swine wastewater as researchers' team revealed inoculum. At 32°C, they observed a reduction of 53.11 % in volatile solids and a biogas yield of 270 L with 63 % methane, and at 26°C, a decrease of 45.76 % in volatile solids and a biogas yield of 171 L with 61 % methane (Çelik *et al*., 2016).

Lactose recovery and utilisation: Whey is a possible raw material for developing lactose and whey-based value-added products because lactose (4-O-d-galactopyranosyl-d-glucose) is a fundamental component of its solids (70–72 % total solids). Because it functions as dietary fibre and has prebiotic qualities, lactose offers a number of advantages from a health and nutritional standpoint. In this way, lactose helps the body absorb different minerals like calcium, phosphorus, and magnesium through the intestinal tract (Jambrak *et al*., 2018). Additionally, it is used by intestinal bacteria as a food source and a substrate for the formation of lactic acid and short carbon cycle fatty acids (SCFA), which creates a moderately acidic reaction in the intestine and inhibits the growth and spread of dangerous bacteria (Zandona *et al*., 2021). Additionally, because to its low glycaemic index (which is half that of glucose), it has less of an effect on blood sugar levels. Several techniques, such as evaporation to concentrate the whey, crystallisation of the lactose from concentrated whey, and centrifugation or decantation to separate the resulting crystals, can be used to recover lactose from deproteinized whey (such as whey permeate obtained by ultrafiltration). Since lactose is the primary factor contributing to whey's high BOD and COD levels, its recovery might more than halve the BOD value.

In this approach, lactose recovery may be able to address both environmental and waste management issues. The recovered lactose may also be supplied to the food, pharmaceutical, dairy, and beverage (e.g., food-grade or pharmaceutical-grade) businesses, depending on its quality (Chatzipaschali and Stamatis, 2012). It is typically employed as an excipient in the pharmaceutical business as well as in the food and confectionery industries, particularly in baking as a crust browning enhancer. Furthermore, the microbial breakdown of lactose can be used to create novel whey-based products (Gadhe *et al*., 2015).

Lactic acid: Two isomers of lactic acid (LA; 2-hydroxy propanoic acid) exist as prospective platform chemicals, L (+) and D (-). Since D (-) is toxic to humans, only the D (+) isomer can be manufactured via biotechnology and employed in the food sector. Contrarily, D (-) can be transformed into a number of important industrial compounds, including pyruvic acid, acrylic acid, 1,2-propanediol, and lactate ester, and has a variety of uses in the synthesis of polymers based on polylactic acid (PLA). LA and its derivatives have long been used as preservatives and acidifiers in the food, pharmaceutical, textile, leather, and chemical sectors. Its production has recently expanded due to its use in the manufacture of ecologically friendly biodegradable polymers (PLA) to replace a sizable portion of petroleum-based plastics and assist in climate change mitigation (Jambrak *et al*., 2018). With the help of bacteria, fungi, and yeast, lactose can be successfully transformed to lactic acid by fermentation. It is a fermentation by-product of various microorganisms, including filamentous fungi *Rhizopus oryzae, Lactobacillus, Bacillus, Enterococcus, Lactococcus, Pediococcus, Streptococcus*, and *Candida*. A select few of these, including the native LA producers Lactobacillus delbrueckii and *Sporolactobacillus, Escherichia coli, Bacillus coagulans, Corynebacterium glutamicum, and B. licheniformis,* are employed by the industry. Using Kluyveromyces marxianus var. marxianus for LA production has also been successful. LA is first produced using pricey, pure lactose, glucose, or sucrose. Due to the expensive cost of pure raw materials, research is focused on more practical and sustainable methods, such as getting LA from waste effluents like whey. Prior to the creation of LA, whey must be processed using membrane methods to lower its protein content and enhance the concentration of lactose and mineral salts (Zandona *et al*., 2021).

Bioplastic: A crucial tactic for maximising the utilisation of agricultural and industrial wastes and raising the potential income of the entire bioprocessing chain for the creation of bioplastics is the interlinkage of biotechnology processes. Due to the ease with which the lactose in whey permeate may be transformed into polyhydroxyalkanoates (PHAs) and polylactic acid (PLA), the use of cheese whey as a substrate for the manufacturing of bioplastics has recently gained attention. The industries of packaging, spraying materials, device materials, electronic products, agricultural products, automation products, chemical media, and solvents can all make use of the bioplastics that were thus generated (Musci *et al*., 2016).

Bioethanol: Future fuel alternatives that are environmentally beneficial have stood out, particularly bioethanol (green fuel). Bioethanol is useful in lowering air pollution and minimising global warming because it doesn't emit any hazardous gases during combustion. Legislative incentives are used to support its production as a result everywhere in the world. The majority of the ethanol purchased in the USA in 2007 originated from maize, with the remaining 5% coming from wheat, barley, or agro-industrial wastes (such as cheese whey and some beverage residues). Diverse strategies for producing bioethanol have been created based on applying non-food agriculture crops and various agro-industrial wastes to prevent the absence of food crops or rural assets and alleviate the environmental impact of industrial and agricultural wastes (Zandona *et al*., 2021). Due to its high organic load and high contamination potential, whey has distinguished itself as a viable substrate for bioethanol synthesis among these wastes (Chatzipaschali and

Stamatis, 2012). The bioconversion of whey into ethanol attracts attention, even though the conversion of lactose and other whey constituents into bioethanol is hardly competitive with the present methods employing sugarcane, maize starch, or utilising lignocellulosic biomass as raw material. Due to the low lactose content and low bioethanol yield (2–3%), direct fermentation of whey is not economically feasible and results in expensive capital expenditures at the distillery. Whey concentrated by ultrafiltration and/or reverse osmosis, which has a high lactose content, can be fermented to produce more bioethanol. Lactose must be enzymatically hydrolyzed before Saccharomyces cerevisiae can ferment it into alcohol since the traditional industrial strain lacks the enzymes necessary to break down lactose. In contrast, *Kluyveromyces marxianus* strains, often employed yeast strains for the fermentation of lactose into bioethanol, can metabolise lactose (Jambrak *et al*., 2018).

Polylactic acid: One of the most promising environmentally friendly (green) plastics of the time, polylactic acid (PLA) is a biodegradable bio-polyester created by condensation of lactic acid (LA) monomers, and shares many characteristics with polystyrene (PS) and polypropylene (PP). PLA has a GRAS rating (Generally Regarded as Safe) because of its low toxicity, making it suitable for use in food packaging. It can be composted in earthen trenches with other biodegradable materials, such as plant and animal wastes, because it is biodegradable, and its disposal won't adversely affect the environment (Zandona *et al*., 2021). Despite being biodegradable, it will persist for years like petroleum plastics if incorrectly disposed of in landfills. Three distinct types of PLA exist poly (l-lactic acid), poly (d-lactic acid), and poly (dl-lactic acid (PDLLA). Although PLLA is acceptable for industrial usage, its low thermal stability (melting point 180 °C) restricts its applicability. In contrast, PLLA and PDLA stereo complexes (SC) are more heat stable (melting point 230 °C), hydrolysis resistant, and have superior mechanical qualities (38). Since the demand for d-LA increased due to the manufacture of PLA, eco-friendly microbial d-LA production has gained attention. *Sporolactobacillus laevolacticus, Lactobacillus plantarum, Sporolactobacillus ilulins,* and *Lactobacillus bulgaricus* are examples of wild-type bacteria that can manufacture it (Musci *et al*., 2016).

*Single cell proteins:*One of the fundamental steps in addressing the issue of rising demands for novel and alternative food sources is the production of single cell protein (SCP). According to its definition, SCP is a "protein extracted from cultivated microbial biomass," which refers to dehydrated cells of various microorganisms (algae, actinomycetes, bacteria, yeast, moulds, and higher fungi) grown in large-scale culture systems for use as a source of protein in human food or animal feed. In place of pricey conventional sources like soy meat and fish meat, it can be used as a protein supplement (Chatzipaschali and Stamatis, 2012). Utilizing whey as a substrate for the synthesis of SCP may lower its polluting potential and produce a product with enhanced value. Whole whey or whey permeate a useful substrate for synthesising SCP through the utilisation of lactose directly by lactose-consuming microbes or indirectly for a microorganism that does not grow on lactose following the breakdown of lactose by enzymatic or chemical methods. The *Kluyveromyces* species, particularly *K. marxianus or K. fragilis* strains, which are GRAS microorganisms and offer benefits of strong growth yields, have been the subject of the most research for SCP manufacture from whey (Zandona *et al*., 2021).

CONCLUSIONS

Environmental concerns have compelled governments to pass laws governing the disposal of whey, which has prompted the dairy sector to look for alternative strategies and prospects for the management of dairy wastes. Whey recycling and reuse have become major scientific problems in reducing dairy waste because of their significant polluting potential. These scientific efforts led to the creation of several environmentally friendly whey disposal techniques. Whey is an excellent starting point for developing various innovative products or a perfect substitute for more conventional compounds due to its components.

REFERENCES

Zandona, E., Blažić, M., & Režek Jambrak, A. (2021). Whey utilization: Sustainable uses and environmental Approach. *Food Technology and Biotechnology*, 59(2): 147-161.

Chatzipaschali AA, and Stamatis AG (2012). Biotechnological utilization with a focus on anaerobic treatment of cheese whey: Current status and prospects. *Energies* 5(9):3492–525. https://doi.org/10.3390/en5093492.

Režek Jambrak, A., Vukušić, T., Donsi, F., Paniwnyk, L., & Djekic, I. (2018). Three pillars of novel nonthermal food technologies: food safety, quality, and environment. *Journal of Food Quality, 2018*.

Çelik, K., Önür, Z. Y., Baytekin, H., & Coşkun, B. (2020). 3. WHEY PROCESSING: Utilization and Major Products. *Whey Every Aspect*, 33.

Gadhe A, Sonawane SS, Varma MN (2015). Enhanced biohydrogen production from dark fermentation of complex dairy wastewater by sonolysis. *International Journal Hydrogen Energy* 40(32): 9942–51.

Musci, I. (2016). Nutrients in whey and nutritional properties of whey products. *Whey every aspect. Istanbul, Turkey: Tudás Alapítvány*, 70-91

NANO UREA- A PIONEER INPUT FOR SUSTAINABLE AGRICULTURE

Mo Danish[1*], Mohammad Hashim[2], Virendra Singh[3], Mukesh Kumar[4] and Ankit Singh[5]

[1]PhD Scholar, School of Agriculture Science and Engineering, IFTM University, Moradabad, Uttar Pradesh- 244102
[2]Scientist, Senior Scale, ICAR-IIPR, Kalyanpur, Kanpur, Uttar Pradesh- 208024
[3]Professor and Director, School of Agriculture Science and Engineering, IFTM University, Moradabad, Uttar Pradesh- 244102
[4]Associate Professor- cum-Senior Scientist, Dept. of Agronomy, Dr. Rajendra Prasad Central Agriculture University, Pusa, Samastipur, Bihar- 848125
[5]Assistant Professor, Dept. of Agronomy, K.N.I.P.S.S. Sultanpur, Uttar Pradesh- 228118

Corresponding author email: danish11282@gmail.com

ABSTRACT

Synthetic fertilizers boost crop output, but they can alter the mineral composition of the soil and reduce soil quality. As a potential substitute, the development of nano-scale fertilizer ensures higher agricultural productivity, profitability, and soil restorative capability without disturbing the environment. The demand for Nano-urea is considerably lower than that for prilled urea fertilizers to meet the plant's need for nitrogen since its absorption efficiency is usually approximately 80% versus the prilled version of urea.

INTRODUCTION

After the advent of high-yielding and fertilizer-responsive cultivars, fertilizers became progressively important in boosting agricultural production in developing nations. Despite this, it is generally known that inadequate fertilization and a drop in the amount of organic matter in the soil have contributed to a decline in crop yields for numerous crops. Since most Indian soils are low in nitrogen, the crop needs a lot of fertilizer, particularly nitrogen, which is crucial to many physiological processes in plants. More than 82 per cent of the nitrogenous fertilizers used for most crops are primarily urea. About 33 million tonnes of urea are applied to different crops annually. India bought more than 11 million metric tonnes of urea in the financial year 2021, continuing an upward trend in urea imports (Anonymous, 2020–21). Concerning rice's growth characteristics, nitrogen fertilizer has a beneficial impact on yield and yield-contributing components through the photosynthetic process, flowering, fruiting, and maturity phase (Nath *et al.*, 2018). The ministry of chemicals and fertilizers informed a standing Committee of Parliament that in 2025, eight plants are planned to generate 44 crore bottles of Nano- urea, replacing 44 crore bags, or roughly 200 lakh tonnes (1 bag is 45 kg urea) of urea, which is 55 to 60% of India's requirement of 300 to 350 lakh tonnes. However, low N levels may prevent realising the highest yield potential.

Worldwide, excessive and inappropriate nitrogen fertilizer use severely impacts soil and water quality (Bashir et al., 2020) and human and environmental health (Rathnayaka *et al.*, 2018). Consequently, lodging is created, which results in a surge in insect pest attacks, leading to inferior quality produce. According to the researcher, between 40 and 70 per cent of the nitrogen from applied fertilizers is lost to the environment and cannot be used by crops, resulting in losses that are significant in terms of economic and ecological impacts, as well as significant environmental degradation (Guo *et al*., 2005). These fundamental issues can be resolved by corresponding fertilizer availability and crop demand, which has the potential to lower nutrient losses while raising nutrient efficiency. The Nano-fertilizer would be the ultimate choice in the current situation.

Nano-fertilisers are one of the most promising customized substances being explored for soil or foliar applications. Under Atmanirbhar Bharat and Atmanirbhar Krishi, Ramesh Raliya, an Indian researcher, produced the first Nano- urea for farmers worldwide using a unique, trademarked methodology that relies on imports to feed its urea demands. The term "Nano- fertilizer" refers to compounds with Nano-particles enclosed in them that gently release nutrients to plants and are generally manufactured by using physio-chemical, biological techniques of Nano-technology, including several extracts of a plant part or microbial origin.

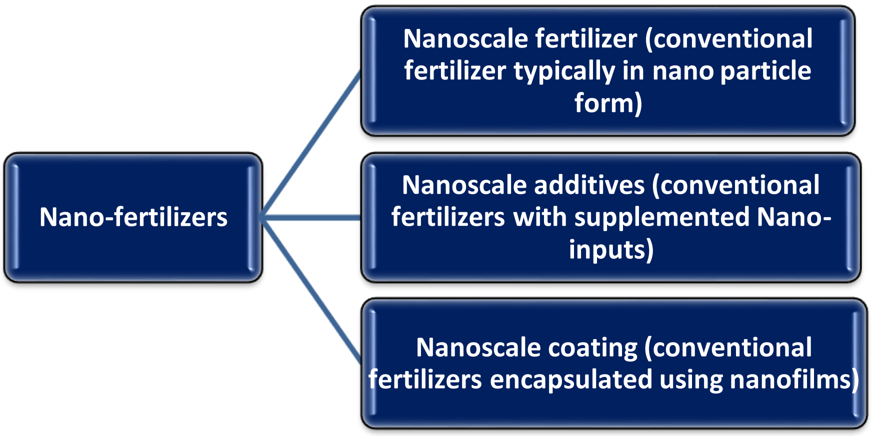
NANO-FERTILIZER- AN ESSENTIAL INPUT FOR AGRICULTURE

Due to various issues confronting agricultural scientists in the agriculture sector, the production system is facing notably decreased crop yields, falling soil organic material richness, increased levels of multi-nutrient shortages in the soil system, unfavourable climatic effects, arable land and water resources, etc. Moreover, farmers frequently use fertilizers several times to attain targeted yields. The excessive use of chemicals reduces soil fertility and raises salt concentrations, leading to crop injury. However, improper fertilizer application without control over nutrient release patterns degrades the overall product's quality. Therefore, manufacturing fertilizers with a gradual or controlled release is essential for increasing crop yield, productivity, and quality. They have great availability and absorbency because of their increased surface area per unit volume size ratio and Nano-scale dimension. Nano-fertilizers have particles less than 1-100 nm in at least one dimension, making them easier to absorb from the soil or leaves and increasing the amount of photosynthates and biomass needed for healthy crops. Both crop yields and nutrient utilization efficiency improved when traditional urea and nitrogen were applied in the foliar form at important crop growth phases (Kumar *et al*., 2020). Compared to conventional fertilizers, Nano-fertilizers have advantages in terms of treatment, low demand, a slowly released strategy, a decrease in transportation and deployment cost and lesser salt concentration in soil.

Based on the nutrient needs of plants, three aspects of Nano- fertilizer are defined below:

Macronutrient nano fertilizers	Micronutrient nano fertilizers	Nanoparticulate fertilizer
• Elevated concentrations of nutrients needed for traditional agricultural activities, are includes • Eg. N, P, K, Ca, S	• About <100 ppm of trace elements are required for metabolic activities of plant. • Eg. Fe, cu, zn	• It exhibited the capability to improve plant growth and deveopment. • Eg. Silicon dioxide, and carbon nanotubes

According to the types of formulations, Nano-fertilizers have been proposed:



WHY DOES NANO-UREA (liquid form) MUCH PREFERABLE OVER CONVENTIONAL UREA?

- *Better Efficiency:* Liquid Nano-urea can have an efficiency of up to 85% over traditional urea (approximately about 25%). Nano-structured fertilizers can be employed as an innovative strategy for supplying nutrients to plants because of their distinguishing qualities. The distinctive characteristics of nanoparticles, such as their high absorption, accessibility, prompt supply of nutrients, enhanced surface-to-volume ratio, and controlled-release dynamics to particular areas, make them a promising plant growth enhancer. In addition, nano-urea does not lose through gases form over prills form of urea.
- *Targeted supplying of nutrients to crops:* The plant absorbs liquid Nano scale urea sprinkled precisely on its foliage, leading to a targeted supply of nutrients to crops because it is absorbed through stomata and pores on the leaf's epidermis.

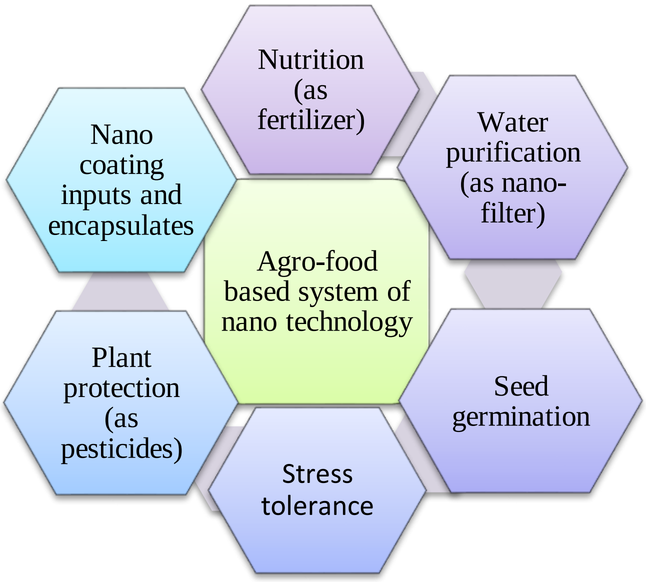


Fig 1- A**applications of nanotechnology increasing crop output** in **agro-food systems**

- *Fiscally feasible:* At least each sack of urea could be effectively replaced by a bottle of nano-scale urea. Currently, there is no subsidy on the half-litre bottle of liquid Nano-urea, which costs ₹240/-, over a sac of prilled urea, which costs approx. ₹242/- for 45 kilograms at a highly discounted rate, including a government subsidy. Compared to farmers' conventional methods, using Nano-urea boosted annualized returns by approximately 7% overall. In addition, the yields increased by 11% when evaluated in fields using organic agricultural methods (no chemical fertilizers other than Nano-urea).

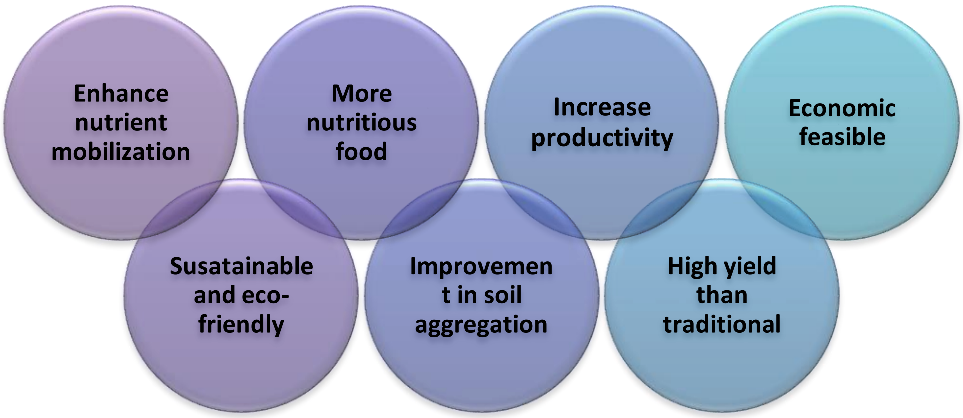
APPLICATION TACTICS, TIME AND DOSES OF NANO INPUT MATERIAL

The first spray should be applied at the active tillering or branching stage (30-35 days after germination or 20- 25 days after transplanting), while the second application is applied 20-25 days later or before the crop is at the flowering stage. Nano-urea @ 2 ml to 4 ml mixed well in 1 litre of water sprinkled on plant foliage when the plant attains its critical stages led to efficiently fulfilling nitrogen requirements. Two foliar sprays should be applied to get the best response, and further, the number of sprays can be increased based on crop needs and demand.

HOW DOES NANO-UREA FUNCTION?

Stomata and other pores effectively absorb Nano-urea sprinkled on the leaf. From the source to the sink inside the plant, it is simply transferred by phloem as per the requirements. For proper plant growth and development, unused nitrogen is retained inside the plant vacuole and released over time. The nitrogen in Nano-urea undergoes hydrolysis within the plant system, converting to ammonical and nitrate forms. According to research, plants treated with Nano-fertilizer accumulated more nitrogen and improved soil pH, soil moisture, CEC, and nitrogen availability over the prilled form of fertilizer. Even though the pattern of nutrients released by N appeared superior for Nano-fertilizer over traditional fertilizer

ADVANTAGES OF NANO-UREA



1) Minimize the necessity for prilled urea by at least 50%. A single bottle of Nano-urea (500 ml) has the same value as one urea bag in terms of nutrient status.
2) Urea is less expensive than conventional urea, so farmers' input costs are reduced, increasing their revenue.
3) It contributes to tackling climate change, and ecological development improves yield, soil quality, and the nutritional value of products.
4) Compared to a bag of subsidized urea fertilizer, one bottle of Nano- urea's weight contains the same amount of value (45 kg) and is offered to the farmers for 10% less in terms of monetary value.
5) The cost of warehousing and logistics would drop dramatically due to easier and more affordable transportation. As a result, it may reduce urea fertilizer imports.
6) As of 2019, across India, over 1,000 farmer field experiments have been conducted on more than 94 crops across 21 states to assess their effectiveness. The analysis revealed an average of about 8% enhancement in crop yield and higher efficiency approx. 80% rarely means wastes and extremely effective to utilize prilled form urea about 30-40%, which saves farmer's money approximately between ₹5,000/- and ₹10,000/- per hectare.

APPLICATION GUIDELINES

1. Shake well urea bottles thoroughly before use.

2. To sprinkle these Nano-molecules on the foliage, use a flat fan nozzle for spray in the early daytime or evening to escape dew.
3. It is suggested to reapply the Nano-urea spray if rain falls within 12 hours after the initial application.
4. Nano-urea must be applied within two years of its manufacturing date to achieve better results.

SAFETY AND PRECAUTIONS

Safety and Precautions

- Keep out of the reach of kids and pets to assured safety and store in a cool,dry safe place
- Although nano urea is non-toxic and assure for the safety and well being of almost all creatures viz. animal,plants etc. while nonetheless advised to use protective gloves as well as a face mask when applying it to crops.
- According to Department of Biotechnology and OECD international norms, nano materials viz. urea, Zn as well as Cu containg fertilizer have all undergone bio safety and toxicity and have all been deemed suitable and safe for usage by users without posing any risks.

FUTURE OUTLOOK

1. To accelerate towards sustainable agriculture, forthcoming research must concentrate on producing various understanding concepts in respective unexplored areas.
2. Studying and examining on a wider basis led to ensuring biosafety and toxicity must be prioritized and focused on the suitability of fertilizer for particular crops as well as soil types.
3. Precise studies and research must be prioritized concerning the residual effect of Nanoparticles in edible portions of the plant, which are critically essential for consumption.

CONCLUSION

The effect of foliar feeding of Nano- urea during the crucial vegetative phase of a plant efficaciously satisfies its nitrogen demand. It has been shown to boost seed germination, biomass production, plant height, many root systems, quality of soil, rate of return, and antioxidant composition in fruit, leading to enhanced crop yields over ordinary urea. Using nano-materials to consolidate biological control formulations is anticipated to have the biggest impact and will considerably minimize environmental risks. At the prescribed application amounts, Nano- urea seems to be fully safe for people, livestock, and rhizosphere microorganisms. To fully benefit from Nano- fertilizer and Nano- urea enable sustainable agro–based practices in the scenario of climate change and the danger of causing environmental issues. Researchers and policymakers must accept responsibility by sharing more awareness and facts about the pros and cons of Nano- urea and Nano- fertilizers.

REFERENCES

Bashir, I., Lone, F. A., Bhat, R. A., Mir, S. A., Dar, Z. A., and Dar, S. A. (2020). Concerns and threats of contamination on aquatic ecosystems. In bioremediation and biotechnology, sustainable approaches to pollution degradation, Berlin, Germany: Springer. 1–26.

Chhipa, H. (2016). Nano- fertilizers and Nano- pesticides for agriculture. *Environmental Chemistry Letters*, *15*(1), 15–22.

Guo, M., Liu, M., Hu, Z., Zhan, F. and Wu, L. (2005). Preparation and properties of a slow release np compound fertilizer with superabsorbent and moisture preservation. Journal of Applied Polymer Science, *96*, 2132-2138.

Indian Farmers Fertilizer Co-oprative Limited, IFFCO sadan, C-1 District Centre, Saket, New Delhi-110017, New Delhi, India

Khodakovskaya, M.V., De Silva, K., Biris, A.S., Dervishi, E. villagarcia, H. (2012). Carbon Nano-tubesinduce growth enhancement of tobacco cells. ACS Nano, *6*(3), 2128–2135.

Kumar, R., Singh, R K., Panda, A. and Singh, S. K. (2021). Nano urea: An efficient tool for precision agriculture and sustainability. *Vigyan Varta*, *2*(9): 72-74.

Mastronardi, E., Tsae, P., Zhang, X., Monreal, C., and Derosa, M. (2015). Strategicrole of Nano-technology in fertilizers: potential and limitations. Berlin, Germany

Meghana.*T.K.*, Wahiduzzaman., M.D., Vamsi.W. 2021. Nano-fertilizers in Agriculture. *Acta Scientific Agriculture*. 5.3, 35-46.

Mikkelsen, R. 2018. Nano-fertilizer and Nanotechnology: a quick look. *Bettercrops*. 102: 18–19.

Rajonee, A.A., Nagar, F., Ahmed, S. and Imamulhuq, S.M. 2016. Synthesis of nitrogen nano fertilizer and its efficacy. *Canadian Journal of Pure and Applied Science*. *10*(2), 3913-3919.

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INVASIVE SEAWEED IMPACT AND MANAGEMENT IN INDIA

Hari Prasad Mohale

Department of Fisheries Biology and Resource Management
Fisheries College & Research Institute, TNJFU, Thoothukudi- 628 008, Tamil Nadu.

Correspondence author email: haricof92@gmail.com

ABSTRACT

Exotic creatures can cause ecological and economic losses in marine habitats when they are introduced. With 407 introduced algal species, seaweeds worldwide make up a sizable portion of these non-indigenous species. The taxonomically varied group of marine plants known as seaweeds is where land plants separated more than 50 billion years ago. Modern molecular systematic data suggests that these plants are enormously diversified, contrary to the traditional classification of these plants. Seaweeds are helpful to humans in various ways, such as a source of pharmaceuticals, dietary supplements, and industrial chemicals, as well as a possible biofuel and CCS candidate (carbon capture and sequestration).

INTRODUCTION

The term "seaweed" is inaccurate; it is a plant with many purposes. The word's etymology indicates that it has been in use since the 1570s when people were less aware of its uses. The names "sea-plant" or "sea-vegetable" would be a better substitute; however, they are not as well known. Seaweeds are watery, non-vascular marine macroalgae (Bast, 2014). The term "algae" in this article refers to aquatic photosynthetic organisms known as microalgae and seaweeds (also known as marine macroalgae). Algae play a crucial role in the aquatic ecosystem by providing the energy foundation of the food web for all aquatic organisms. They also offer a number of environmental advantages and ecosystem services, including reducing eutrophication, capturing carbon dioxide or sequestering it, reducing ocean acidification, providing habitat, and protecting shorelines (Cai *et al.*, 2021). The majority of foreign seaweeds were introduced accidentally. Due to distinguishing characteristics (such as the ability to spread successfully), some species appear to be more likely to become invasive. However, it is not necessarily certain that they would successfully establish in the new area or become detrimental once introduced. Because of this, it is impossible to categorise a particular species of seaweed as invasive in an absolute sense.

Moreover, when an organism becomes invasive, it may exhibit various behaviours and impact many scales and locations (Petrocelli and Cecere, 2015). The scientific community has recognised the ecological importance of seaweeds by evaluating their ecosystem services, including regulating, provisioning, and cultural services, which directly or indirectly promote human well-being. Algae are important regulators of the aquatic environment because they serve as a source of primary and secondary production, safeguard coastal areas, and serve as modifying grounds. Moreover, various aquatic creatures use seaweed as a food source, supporting provisioning services for a diverse spectrum of invertebrates. Moreover, seaweeds have economic importance for society and are an important component of each region's cultural legacy and identity (Pacheco *et al.*, 2020).

SEAWEED FLORA OF INDIA

The Indian subcontinent, which has a coastline of over 7,500 km, has some of the longest uninterrupted coastal ecosystems in the world and is home to a wide variety of seaweed. The most significant seaweeds in India in terms of their pervasive nature are Sargassum and Turbinaria among brown seaweeds, Hypnea and Kappaphycus among red seaweeds, and Ulva and Caulerpa among green seaweeds. Most seaweeds in India are found around the beaches of Gujarat, Kerala, and Tamil Nadu. I believe Mandapam in Tamil Nadu has India's greatest variety of seaweed species. While there are hints that the reefs surrounding the Andaman and Nicobar islands sustain greater seaweed diversity, the area nears the Pamban Bridge that connects the island of Rameswaram to the mainland. An increase in nutrients for the opulent growth of seaweed is considered to result from the mixing of the eastern Bay of Bengal with the southern Indian Ocean at Mandapam (Palk Strait). For those who enjoy seaweed, a trip to this location, which we will call "Botanical Beach," might be a memorable one that is simple to combine with a trip to Rameswaram or Dhanushkodi. One can rent a local manual or motorised dinghy to travel beneath the Pamban Bridge and the nearby locations. One can even go snorkelling because, in good weather, the sea is remarkably tranquil (Bast, 2014).

ENVIRONMENTAL BENEFITS AND ECOSYSTEM SERVICES

Seaweeds and microalgae provide important ecological functions and environmental advantages. It is unnecessary to directly employ freshwater, feed, fertiliser, or terrestrial soil to cultivate seaweed. Microalgae can be raised on marginal land in arid and desert climates and in freshwater or marine habitats. The photosynthetic process of seaweeds and microalgae can lessen eutrophication, treat wastewater, lessen ocean acidification, and capture/sequester carbon by removing nutrients (nitrogen and phosphorus) from surrounding waters and absorbing carbon dioxide. The cultivation of seaweed and microalgae can help with the to combat climate change through a variety of mechanisms, such as producing low-carbon footprint human foods, animal feeds, and fertilisers, (ii) capturing or sequestering carbon, and (iii) lowering methane emissions from cattle farming that uses specific seaweeds as feed supplements.

IMPACTS OF SEAWEED FARMING ON NATIVE SEAWEED POPULATIONS

Imported non-native seaweeds risk outcompeting native flora and animals, changing the ecology in their new habitat, and becoming invasive. On various scales within the recipient system, further possible effects can take the form of altered ecosystem functions, such as changes in community productivity, habitat complexity, and biodiversity. As a result of the invasion of non-native seaweeds, the species richness of native seaweed communities has been observed to have decreased. Although there is evidence that seaweed farming can lower native seaweed biomass in seagrass environments, comparable research has not been carried out in the WIO region, and investigations on consequences on recipient macrophyte systems have primarily focused on seagrasses.

In general, there is limited scientific knowledge about the ecological processes and natural habitats of seaweed in this region. Given that *Eucheuma denticulatum* and *Kappaphycus alvarezii* are native to the Western Indian Ocean (WIO) region, it is difficult to distinguish the various strains visually, making it difficult to detect a potential invasion of farmed SEA haplotypes (we will refer to these as "haplotypes" of SEA or EA types" in this review). However, growth rate assays have shown that Sea *E. denticulatum* often exhibits a greater growth rate than native *E. denticulatum (Halling, unpubl.)*, indicating this could be a possible problem. It is still uncertain if the introduced eucheumatoids are competing with native populations. Parallel to this, newly introduced eucheumatoids might also face competition from other seaweed species, such as significant habitat-forming species like Sargassum spp (Eggertsen and Halling, 2021).

CONCLUSION

There may not be much influence on the environment from seaweed farming; a major worry is the introduction of non-native seaweeds. Due to their capability for rapid growth rates, efficient asexual reproduction by fragmentation, and simple substrate attachment, seaweeds like eucheumatoids must note this. Conclusion: Precautionary measures are always advised because any seaweed, tropical or temperate, that possesses those traits and is introduced in an environment with favourable conditions such as temperature, salinity, presence of settling substrate, etc., could potentially be at risk of spreading into its new habitat.

REFERENCES

Bast, F. (2014). Seaweeds: Ancestors of land plants with rich diversity. *Resonance, 19*(2), 149-159.

Cai, J., Lovatelli, A., Aguilar-Manjarrez, J., Cornish, L., Dabbadie, L., Desrochers, A., & Yuan, X. (2021). Seaweeds and microalgae: an overview for unlocking their potential in global aquaculture development. *FAO Fisheries and Aquaculture Circular*, (1229).

Eggertsen, M., & Halling, C. (2021). Knowledge gaps and management recommendations for future paths of sustainable seaweed farming in the Western Indian Ocean. *Ambio*, *50*(1), 60-73.

Pacheco, D., Araújo, G. S., Cotas, J., Gaspar, R., Neto, J. M., & Pereira, L. (2020). Invasive seaweeds in the Iberian Peninsula: A contribution for food supply. *Marine drugs*, *18*(11), 560.

Petrocelli, A., & Cecere, E. (2015). 11 Invasive Seaweeds: Impacts and Management Actions.

GENOME EDITING OF CROP PLANTS

Nimmy M.S.[1], Ramawatar Nagar[1], Billeswar Mohanta[1], S Lekshmy [2] and Vinod Kumar[3]

[1]ICAR - National Institute for Plant Biotechnology, New Delhi -110012
[2]ICAR -Div. of Plant Physiology, Indian Agricultural Research Institute New Delhi -110012
[3]Department of molecular biology and genetic engineering, Bihar Agricultural University, Sabour, Bhagalpur, Bihar - 813210

*Corresponding author email: biotech.vinod@gmail.com

ABSTRACT

Over several decades, researchers exploited screen and selection to improve crop varieties for higher yield, better nutrient and water use efficiency, etc. However, with the increase in population and due to negative consequences of the green revolution on plants and soils, it is not easy to further enhance crop productivity. Genome editing is a new technique where one can modify the function of a gene by modifying, deleting and introducing the DNA sequence of a plant or living organism. The different genome editing tools include ZFN, TALENS and CRISPR/Cas. These site-specific nucleases make nicks in the DNA, which will be repaired by the cells' innate repair mechanism, resulting in mutations.

INTRODUCTION

The green revolution brings a big gift from researchers to humanity, satisfying the need for food for a large population. The varieties were high-yielding and highly nutrient-responsive in nature. The technological expansion also paved the way to achieve higher yields. However, over the year, these interventions also showed some negative consequences. The soil fertility started declining, the nutrient responsiveness also started decreasing, disease and pest incidence increased, and again climate change made things more difficult.

A LOOK INTO THE HISTORY OF CRISPR-BASED GENOME EDITING

If we look back, the first step for today's scientific achievement (CRISPR-based genome editing) for mankind was started in 1987. CRISPR-Cas system is an acquired immune system in prokaryotic organisms, was finally proven through scientific experiments in 2007, with the help of a lactic acid bacterium, *S. thermophilus*. (Barrangou *et al*., 2007). The first genome editing technique through CRISPR-Cas9 was developed in 2012 with the help of *Streptococcus pyogenes*. Finally, in the early time of 2013, scientists were able to engineer/edit mammalian cells using CRISPR-cas9 technology.

WHY CRISPR-BASED GENOME EDITING?

Because of its high efficiency, low cost and high specificity, CRISPR-Cas9 technology received more popularity in the market of genome editing technology, the trend has changed toward CRISPR-Cas9-based genome editing technology from previous other genome editing tools, and today it is widely accepted.

WHAT ARE SDN1, SDN2 AND SDN3 MUTATIONS?

Genome editing leads to three categories of mutations known as SDN1, SDN2 and SDN3. In the first category of SDN1 mutation, the edited plant will be free from foreign DNA because when double-stranded nicks are produced in the cell, the natural repair mechanism by homologous end joining happens, leading to gene function modification. These changes are similar to those natural mutations occurring in plants. In SDN2 mutations, an exogenously supplied DNA fragment facilitates repair with the desired mutation to be incorporated into the target DNA. Based on homology, the pairing will result in desired mutations. This type of mutation is also considered natural. The third category of SDN3 mutation falls under transgenics as it facilitates the introduction of foreign genes.

CONCLUSION

Genetic engineering technology and transgenic plants have immense potential to solve major problems in Agriculture. However, public concerns about various aspects of transgenic plants impede crop improvement programmes. Until now, many of the developed transgenic plants are not commercially released for cultivation due to strict guidelines. Hence the new rule by GoI, which exempts SDN1 and SDN2 genome-edited plants from regulatory rules by considering them transgene-free, is a relief for biotechnologists across India. The genome editing approach can lead to the development of transgene-free plants in 2–3 years compared with the conventional transgenic approach. Genome editing technology can solve many of the problems faced by Indian agriculture. In many countries, genome-edited crops are considered as non-GMOs. Gamma-aminobutyric acid tomato, high oleic acid canola and soybean etc. are some of the genome-edited crops in the global market.

REFERENCES

Barrangou, R., Fremaux, C., Deveau, H., Richards, M., Boyaval, P., Moineau, S., Romero, D.A. and Horvath, P., 2007 CRISPR provides acquired resistance against viruses in prokaryotes. *Science* 315 1709–1712.

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DNA BARCODING AND ITS APPLICATIONS IN AGRICULTURE

Tamanna Sood

Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur

Corresponding author email: soodt29@gmail.com

ABSTRACT

DNA barcoding is a technique that uses a standardized region of the genome to identify species based on their unique DNA sequences. In agriculture, DNA barcoding has become an important tool for species identification and quality control in food products. It can be used to detect food fraud by identifying mislabeled or substituted species in meat, fish, and plant products. DNA barcoding can also be used to verify the authenticity of seeds and plant varieties and to identify pests and pathogens in crops and livestock. DNA barcoding is a powerful tool that can help ensure the safety, quality, and integrity of agricultural products, and it has great potential for future development and applications in this field.

INTRODUCTION

Food security is one of the major challenges in India. As per UNO-India, around 195 million people in India are undernourished, accounting for one-fourth of the world's hunger burden. Moreover, India is ranked 68th out of 113 major countries as per the food security index for 2022. The threat posed by new and invasive pests to agricultural productivity is one of the main food security challenges. The first and most important step in deciding the best course of action for managing such invasive pests is their accurate identification, traditionally based on the morphological diagnosis provided by taxonomic studies. However, molecular data instead of morphological data has emerged as one of the most promising strategies for identifying taxa (Blaxter, 2003). The advances in DNA sequencing technology have enabled researchers to perform easy, low-cost, and quick DNA analysis. This progress in biotechnology played a vital role in developing DNA barcoding (Jinbo *et al*., 2011). DNA barcoding is a DNA-based technique that uses short DNA sequences from a standardized genome region to identify and distinguish between different species. This approach is based on evaluating the variability within one or a few standard regions of the genome called DNA barcodes (Herbert *et al*., 2003). The rationale of this method is that the DNA barcoding sequences unambiguously correspond to each species (i.e., low intraspecific variability) but significantly differ between taxa (i.e., high interspecific variability) (Casiraghi *et al*., 2010).

APPLICATIONS OF DNA BARCODING IN AGRICULTURE

DNA barcoding is applicable in agriculture in the ways given below:

1. Species identification: DNA barcoding can identify different plant and animal species. In agriculture, this is particularly useful for identifying pests, diseases, and weeds that may harm crops. Accurate identifying these organisms can help farmers and researchers develop targeted control measures to prevent crop damage.

2. Food traceability: DNA barcoding can be used to track the origin of food products. This is particularly useful for verifying the authenticity and quality of agricultural products, such as fruits, vegetables, and meat. DNA barcoding makes it possible to identify the species and even the geographic origin of a food product, which can help prevent food fraud and ensure consumer safety.

3. Conservation: DNA barcoding can help conserve endangered plant and animal species. By identifying and cataloguing different species, researchers can monitor their populations and take steps to protect them from threats such as habitat loss and poaching.

4. Seed authentication: DNA barcoding can be used to authenticate the identity of crop seeds. This is particularly important for genetically modified crops or bred for specific traits. With DNA barcoding, farmers can ensure that the seeds they plant are the same as the ones they purchased, which can help prevent crop failures and loss of income.

LIMITATIONS OF DNA BARCODING IN AGRICULTURE

There are several limitations to the use of DNA barcoding in agriculture, including:

1. Incomplete reference databases: DNA barcoding relies on the comparison of the DNA sequence to a reference database of known sequences. However, many species have not been barcoded, and the databases are incomplete, especially for agricultural species in developing countries. This can lead to incorrect identifications or false negatives.

2. Hybridization and introgression: Some plant species can hybridize with closely related species, leading to difficulties in identifying hybrids using DNA barcoding. Similarly, the introgression of genes from wild relatives into domesticated crops can complicate the identification of crop varieties.

3. Purity and quality of samples: DNA barcoding requires high-quality DNA samples, which can be difficult to obtain from processed food products, degraded samples, or mixed samples. Contamination with other DNA, such as from microorganisms, can also lead to inaccurate results.

4. Limited resolution: DNA barcoding can distinguish between some closely related species, but in many cases, it cannot discriminate between different varieties or sub-species within a species. This can limit its usefulness in plant breeding and seed certification areas.

5. Cost and technical expertise: DNA barcoding requires specialized equipment, reagents, and expertise, making it expensive and difficult to implement in some settings. This can limit its availability and accessibility for small-scale farmers or food processors.

CONCLUSION

DNA barcoding is a powerful tool that can provide valuable information in agriculture. It can be used to identify and track different species, verify the authenticity and quality of agricultural products, protect endangered species, and ensure the integrity of crop seeds, but it is not a panacea and must be used in conjunction with other methods of species identification and quality control.

REFERENCES

Blaxter, M. (2003). Molecular systematics: counting angels with DNA. *Nature*, 421(6919), 122-124.

Casiraghi, M., Labra, M., Ferri, E., Galimberti, A. and de Mattia, F. (2010). DNA barcoding: a six-question tour to improve users' awareness about the method. *Briefings in Bioinformatics*, 11(4), 440-453.

Hebert, P.D.N., Ratnasingham, S. and deWaard, J.R. (2003). Barcoding animal life: cytochrome c oxidase subunit 1 divergences among closely related species. *Proceedings of the Royal Society B: Biological Sciences*, 270(supplement 1), S96-S99.

Jinbo, U., Kato, T. and Ito, M. (2011). Current progress in DNA barcoding and future implications for entomology. *Entomological Science*, 14(2), 107-124.

MICROGREENS: SUPERFOOD OF 21ST CENTURY

Shorya Kapoor

Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur

Corresponding author email: shoryak2@gmail.com

ABSTRACT

Microgreens are a new class of speciality food in vegetables. They are gaining popularity among the common folks due to their richness in nutrients, minerals and phytochemicals. These are young and tender greens harvested before the true leaves have emerged. They are found in a pleasing palette of colours, textures, and flavours. Common microgreens grown include mustard, cabbage, radish, buckwheat, lettuce, spinach, etc. Due to their abundance in bioactive compounds and health benefits, their consumption has increased.

INTRODUCTION

The global population has been increasing daily; by 2100, the world's population is projected to reach approximately 10.9 billion. To meet the demand for this ever-growing population, there is a need for a more sustainable, accessible, and nutritious food supply. To serve this purpose, microgreens has emerged as an excellent substitute for mature vegetables rich in nutrients and their small quantities provide more nutrients than their mature counterparts. Since the 1900s, these have been produced in Southern California and showed a gradual increase in popularity owing to their freshness and nutritional benefits over the past decade (Lenzi *et al*., 2019). Not to be confused with sprouts, these are the immature vegetable greens which are harvested after cotyledonary leaves are developed. As these are abundantly nutritional and contains significantly higher amounts of phytochemical, vitamins and minerals, incorporating them into the daily diet of the consumer can result in enhancement of the nutritional status of the diet and also contribute to better health of the consumers (Yadav *et al*., 2019; Xiao *et al*., 2012).

TYPES OF MICROGREENS

A variety of seeds can be used to grow microgreens. The most popular species which are used to grow microgreens are from the following families (View & Club., 2019):

Brassicaceae family: Cauliflower, broccoli, cabbage, watercress, radish and arugula (gargeer)

Asteraceae family: Lettuce, endive, chicory and radicchio

Apiaceae family: Dill, carrot, fennel and celery

Amaryllidaceae family: Garlic, onion and leek

Amaranthaceae family: Amaranth, quinoa, swiss chard, beet and spinach

Cucurbitaceae family: Melon, cucumber and squash

Microgreens are not only grown from vegetable seeds but cereals, namely wheat, rice, corn, oat and barley, along with some legumes such as chickpeas, lentils and beans, are also used. The flavour of microgreens may vary greatly from neutral to spicy, slightly sour or even bitter, depending upon the variety. However, in a broad sense, their flavour is considered strong and concentrated (View & Club., 2019).

NUTRITIONAL STATUS OF MICROGREENS

Microgreens are packed with nutrients. Many studies show they are abundant in many bioactive compounds, including vitamins, minerals, and phytochemicals. Microgreens are a great source of antioxidants. Ascorbic acid is a potent antioxidant and is required for various biological functions, such as wound healing, collagen synthesis, and immune system regulation (Chambial *et al*., 2013). Many researchers have claimed that microgreens contain more or an equal amount of ascorbic acid than their mature counterparts (Yadav *et al*., 2019; Di Bella *et al*., 2020; Xiao *et al*., 2012). Researchers have found that the nutritional profile of microgreens can be up to nine times greater than their mature counterparts (Pinto *et al*., 2015). The concentrations of many nutrients vary slightly in microgreens, but most varieties are rich in K, Fe, Zn, Mg and Cu (Xiao *et al*., 2016). Trace minerals like Cu, Zn and Se, act as cofactors or components of antioxidant enzymes (such as super oxidase dismutase), and are crucial in the endogenous antioxidant defence system of the human body and are therefore referred to as antioxidant minerals (Wolonciej *et al*., 2016). These antioxidant minerals have been frequently examined in microgreen samples and contrasted with their mature plants (Lenzi *et al*., 2019; Pinto *et al*., 2015; Xiao *et al*., 2016). For example, Bottle gourd and water spinach contained higher Cu concentrations at their microgreen stage as compared to the mature stage (Yadav *et al*., 2019).

Microgreens are abundantly rich in phytochemicals like carotenoids and phenolics. From a scientific study, it was found that the carotenoid content in the microgreen phase of wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) was higher than in its seed phase (Niroula *et al.*, 2019). Researchers have found that the Nutrient Quality Score (NQS) of Brassica microgreen like cauliflower was six-fold higher than its mature stage, mainly attributed to the high levels of vitamin A, vitamin E, and carotenoid content in the microgreen stage (Reena *et al.*, 2020).

HEALTH BENEFITS OF MICROGREENS

Being a rich source of minerals, nutrients and phytochemicals, their intake in daily diet is associated with reduced risk of many diseases (Bazzano *et al.*, 2002; Carter *et al.*, 2010). Some of the health benefits of microgreens are stated below:

Heart disease: Consumption of microgreens may reduce the risk of heart diseases as they are rich sources of antioxidants such as polyphenols. According to some studies, microgreens may result in lowering "bad" LDL cholesterol and level of triglyceride (Huang *et al.*, 2016; Tangney and Rasmussen, 2013).

Alzheimer's disease: Foods abundant in antioxidants, including polyphenols, can reduce the probability of diseases like Alzheimer's (Guest and Grant, 2016).

Diabetes: Antioxidant-rich food can reduce the risk of type 2 diabetes. Some experiments show that fenugreek microgreens may increase cellular sugar uptake by 22-44% (M.H., 1996; Wadhawan *et al.*, 2018).

Cancer: Foods abundant in antioxidants, like fruits and vegetables particularly rich with polyphenols, may decrease the danger of different kinds of cancer (Zhou *et al.*, 2016). Some early evidence suggests that sulforaphane, a compound found at especially high levels in broccoli sprouts, may help fight cancer.

Blood pressure: Microgreens are a rich source of fibre and vitamin K, which help to maintain healthy blood pressure.

CONCLUSION

Overall, microgreens have emerged as a novel food, with many studies suggesting their high nutritional and phytochemical qualities than their mature counterparts. Due to their high nutrient density, their potential benefits to human health have increased their acceptability and popularity. However, further research is still required for new interventions in their production and to investigate their potential health benefits.

REFERENCES

Bazzano, L.A., He, J., Ogden, L.G., Loria, C.M., Vupputuri, S., Myers, L. and Whelton, P. K. (2002). Fruit and vegetable intake and risk of cardiovascular disease in US adults: The first National Health and Nutrition Examination Survey Epidemiologic Follow-up Study. *American Journal of Clinical Nutrition*, 76(1), 93–99.

Carter, P., Gray, L.J., Troughton, J., Khunti, K., and Davies, M. J. (2010). Fruit and vegetable intake and incidence of type 2 diabetes mellitus: Systematic review and meta-analysis. *BMJ* (Online), 341(7772), 543.

Chambial, S., Dwivedi, S., Shukla, K.K., John, P.J., and Sharma, P. (2013). Vitamin C in disease prevention and cure: an overview. *Indian Journal of Clinical Biochemistry*, 28(4), 314-328.

Di Bella, M.C., Niklas, A., Toscano, S., Picchi, V., Romano, D., Lo Scalzo, R., and Branca, F. (2020). Morphometric characteristics, polyphenols and ascorbic acid variation in *Brassica oleracea* L. novel foods: sprouts, microgreens and baby leaves. *Agronomy*, 10(6), 782.

Guest, J. and Grant, R. (2016). The Benefits of Natural Products for Neurodegenerative Diseases. *Advances in Neurobiology*, 12, 199–228.

Huang, H., Jiang, X., Xiao, Z., Yu, L., Pham, Q., Sun, J., Chen, P., Yokoyama, W., Yu, L. L., Luo, Y.S., and Wang, T.T.Y. (2016). Red Cabbage Microgreens Lower Circulating Low-Density Lipoprotein (LDL), Liver Cholesterol, and Inflammatory Cytokines in Mice Fed a High-Fat Diet. *Journal of Agricultural and Food Chemistry*, 64(48), 9161–9171.

Lenzi, A., Orlandini, A., Bulgari, R., Ferrrante, A., and Bruschi, P. (2019). Antioxidant and mineral composition of three wild leafy species: a comparison between microgreens and baby greens. *Foods*, 8, 487.

M.H.G. (1996). Dietary antioxidants in disease prevention. *Natural Product Reports*, 13(4), 265–273.

Niroula, A., Khatri, S., Timilsina, R., Khadka, D., Khadka, A., and Ojha, P. (2019). Profile of chlorophylls and carotenoids of wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) microgreens. *Journal of Food Science and Technology*, 56(5), 2758-2763.

Pinto, E., Almeida, A.A., Aguiar, A.A., and Ferreira, I.M.P.L.V. O. (2015). Comparison between the mineral profile and nitrate content of microgreens and mature lettuces. *Journal of Food Composition and Analysis*, 37(3), 38–43.

Renna, M., Stellacci, A.M., Corbo, F., and Santamaria, P. (2020). The use of a nutrient quality score is effective to assess the overall nutritional value of three Brassica microgreens, *Foods*, 9(9), 1226.

Tangney, C.C. and Rasmussen, H.E. (2013). Polyphenols, inflammation, and cardiovascular disease. *Current Atherosclerosis Reports*, 15(5).

View, M. and Club, G. 2019. Microgreens What Will We Cover/?

Wadhawan, S., Tripathi, J., and Gautam, S. (2018). In vitro regulation of enzymatic release of glucose and its uptake by Fenugreek microgreen and Mint leaf extract. International *Journal of Food Science and Technology*, 53(2), 320–326.

Wołonciej, M., Milewska, E. and Roszkowska-Jakimiec, W. (2016). Trace elements as an activator of antioxidant enzymes. *Advances in Hygiene and Experimental Medicine*, 70(0) 1483-1498.

Xiao, Z., Codling, E.E., Luo, Y., Nou, X., Lester, G.E., and Wang, Q. (2016). Microgreens of Brassicaceae: Mineral composition and content of 30 varieties. *Journal of Food Composition and Analysis*, 49, 87–93.

Xiao, Z., Lester, G.E., Luo, Y., and Wang, Q. (2012). Assessment of vitamin and carotenoid concentrations of emerging food products: edible microgreens. *Journal of Agricultural and Food Chemistry*, 60(31), 7644-7651.

Yadav, L., Koley, T., Tripathi, A., and Singh, S. (2019). Antioxidant potentiality and mineral content of summer season leafy greens: comparison at mature and microgreen stages using chemometric. *Agriculture Research*, 8, 165-175.

Zhou, Y., Zheng, J., Li, Y., Xu, D.P., Li, S., Chen, Y.M., and Li, H.B. (2016). Natural polyphenols for prevention and treatment of cancer. *Nutrients*, 8(8), 515.