

## Chemistry in Agriculture – A Review

S. P. Nanda<sup>1\*</sup>, Shimantini Borkataki<sup>2</sup> and Ritu Ranjan Taye<sup>3</sup> and M. Devender Reddy<sup>4</sup>

<sup>1</sup>Department of Chemistry, School of Applied Sciences,

<sup>4</sup>M. S. Swaminathan School of Agriculture,

Centurion University of Technology & Management, Paralakhemundi, Odisha – 761211

<sup>2</sup>Department of Entomology, Assam Agricultural University, Jorhat – 785013

<sup>3</sup>Regional Agricultural Research Station, Karimganj – 788712

\*Corresponding Author E-mail: [spnanda@cutm.ac.in](mailto:spnanda@cutm.ac.in)

Received: 5.05.2020 | Revised: 3.06.2020 | Accepted: 8.06.2020

### ABSTRACT

*Food is the basic requirement for sustenance of human life. Agriculture, for decades, has been closely associated with the cultivation of the soil, production of economically important crops and raising livestock which in turn contributes to national income. However, to meet the demands of the world's ever-increasing population, it has become necessary to maximize the yield and productivity of crops and animal products which is why modern agriculture depends quite heavily on the use of advanced scientific techniques that have been contributed by science and chemistry in particular. In this review, the authors have made an attempt to discuss the contributions of chemistry in agriculture.*

**Keywords:** Agriculture, Chemistry, Photosynthesis, Fertilizers, Pesticides

### INTRODUCTION

Food is the basic requirement for sustenance of human life. Without food there is a seldom possibility of survival for human beings on earth for a long period of time. It is only agriculture that satisfies this need for the entire world's population (Chhibber, 2017 and Baokar et al. 2018). Agriculture, for decades, has been closely related to the cultivation of the soil, production of economically important crops and raising livestock which in turn contributes to national income (Anonymous, 2019). Thus, agriculture is considered as the backbone of a nation and plays a pivotal role in the growth of an economy. However, to meet the demands of growing hunger of the

world's ever-increasing population with diminishing natural resources and unpredictable climate (Plant, 2010), it has become necessary to maximize the yield and productivity of crops and animal products which is why modern agriculture depends quite heavily on the use of advanced scientific techniques that have been contributed by science, and chemistry in particular. Chemistry, also known as the central science, is a scientific discipline that deals with the study of structure, composition, behaviour and changes during reactions involving elements and compounds composed of atoms, molecules and ions (Reinhardt, 2001 and Brown et al. 1999).

**Cite this article:** Nanda, S.P., Borkataki, S., Taye, R.R., & Reddy, M.D. (2020). Chemistry in Agriculture – A Review, *Ind. J. Pure App. Biosci.* 8(3), 241-247. doi: <http://dx.doi.org/10.18782/2582-2845.8129>

This discipline has known to have played a significant role in fulfilling the fundamental needs of crops from the basics of photosynthesis to the utilization of farm produce (Chhibber, 2017) by providing threemajorrequisites viz., water and nutrients to cause the land to produce more abundantly, and protection against deterioration caused by pests and pathogens (Bewick et al., 2019). Thus, advancement in the field of agriculture has become possible due to active research carried out in chemistry as it forms an indispensable part from molecular to organ level (Chhibber, 2017) and henceforth, an endeavour has been made to categorize the contributions of this discipline under various headings in this review.

### Chemistry in manufacturing food through Photosynthesis

Photosynthesis is a natural phenomenon in which green plants transform light energy into chemical energy that can be used to power the operations of the crop, thereby supplying all the agricultural products with essential building blocks. This chemical energy is stored in carbohydrate molecules viz., sugars that are synthesized from carbon dioxide and

water (Bryant & Frigaard, 2006). The net equation:  $6\text{CO}_2 + 6\text{H}_2\text{O} \Rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$  better illustrates the total operation of photosynthesis. For survival and sustenance of any life form on earth, no chemical process is more consequential than photosynthesis as they cannot prepare their own food like autotrophs and rely only on green plant for food. Thus, chemistry has enabled the researchers to understand the underlying principle and mechanism of photosynthesis and to optimize conditions for maximization of the same (Chhibber, 2017).

### Chemistry in water purification

Chemistry has enabled humans to utilize various compounds for water purification that are available in different products or forms. The main purpose of purifying water is how best the undesired and toxic compounds (organic, inorganic, biological contaminants and suspended solids) are removed from the water in order to make it suitable for human consumption. A few of the chemical compounds extensively used for water purification are mentioned in Table 1 (Lenntech, 2020).

**Table 1: List of compounds and chemicals used in water purification (Lenntech, 2020)**

Sl. No.	Compounds	Chemicals/elements involved	Purpose of use
1	Algaecides	Copper sulphate, iron salts, rosin amine salts	Chemical substances used to inhibit the growth of algae. However, they are not known to remove the toxins that the algae releases prior to death
2	Antifoams	Antiform powder (includes substances that are chemically inert) Emulsions (polydimethyl aqueous emulsions)	Antifoams are used to inhibit the formation of foams as it creates problem in industrial operations by reducing the efficiency of equipment thus leading to deterioration in quality of end products
3	Biocides	Oxidising agents (Chlorine, chlorine dioxide, chloroisocyanurates, hypochlorite, ozone) Non-oxidising agents (Acrolein, amines, chlorinated phenolics, copper salts, organo-sulphur compounds, quaternary ammonium salts)	These compounds are used to reduce the population of bacteria and other microorganisms

4	Coagulants	Aluminium as $Al_2(SO_4)_3$ and iron as $FeCl_3$ or $Fe_2(SO_4)_3$	Removal of suspended inorganic (clay and silt) and organic (microbes) particles by facilitating several chemical as well as physical reactions between the particles
5	Flocculants	Cationic and (based on nitrogen), anionic (based on carboxylate ions and polyampholytes) polymers	Removal of suspended particles by producing macroflocs which increases setting rate and ready for sedimentation.
6	Corrosion inhibitors	Passive (chromate, nitrite, phosphate, molybdate), Cathodic (calcium, zinc, magnesium), organic, precipitation inducing, volatile corrosion (morpholine, hydrazine, dicyclohexylamine) inhibitors	These chemicals provide protection in the metal surface through formation of film by absorbing themselves into the surface
7	Disinfectants	Chlorine, chlorine dioxide, ozone, hypochlorite	These are used to kill harmful microorganisms present in water
8	Neutralizing agents (alkalinity control)	Sodium hydroxide solution (NaOH), calcium carbonate, or lime suspension $Ca(OH)_2$ , diluted sulphuric acid ( $H_2SO_4$ ) or hydrochloric acid (HCl)	Neutralize the pH of the water to make it suitable for consumption
9	Oxidants	Hydrogen peroxide, ozone, combined ozone and peroxide, oxygen	Oxidants are used to remove organic and oxidisable inorganic compounds and also to decrease the levels of BOD/COD
10	Oxygen scavengers	These includes volatile compounds (hydrazine – $N_2H_4$ ), non-volatile salts (sodium sulphite – $Na_2SO_3$ ) organic products (carbohydrazine, hydroquinone, diethylhydroxyethanol, methylethylketoxime,	These are used to prevent oxygen from introducing oxidation
11	pH conditioners	Hydrogen chloride (for lowering pH), sodium chloride (for increasing the pH)	Facilitate adjustment of pH to prevent corrosion of pipes, dissolution of lead into water supplies
12	Resin cleaners	Sodium chloride, potassium chloride, citric acid, chlorine dioxide	Regeneration of ion exchange resins result in serious fouling. Thus to remove the contaminants present in resins, resin cleaners are used
13	Scale inhibitors	Phosphate esters, phosphoric acid, polyacrylic acid	These are surface active negatively charged polymers that disrupts the crystallization of structure and formation of precipitates on water surfaces

### Chemistry in manufacturing fertilizers

Fertilizers are chemical substances, either organic or inorganic compounds of natural or synthetic origin that contains high concentration of nutrients required for growth and development of the plants. Besides the three main constituent elements *viz.*, carbon, oxygen and hydrogen, plants need significant amount of nutrients (Cheremisinoff, 1997) and about 40-60% of crop yields are attributed by the use of commercial fertilizers.

Fertilizers are subdivided into two broad categories: organic and inorganic and both are required for promising plant growth. As the name suggests, organic fertilizers are derived from living systems and include manure, fish and bone meal and compost whereas inorganic fertilizers contain higher concentrations of chemicals that may not be

present in enough quantities in the soil (Chhibber, 2017). The decomposition of organic fertilizers is carried out by micro-organisms that are present in the soil to facilitate the release of definite nutrients into the soil which are then taken up by plants and translocated in their system. Inorganic or chemical fertilizers, on the contrary, are highly concentrated with fewer chemical complexities and are synthesized using the Haber-Bosch process. These properties make them suitable to be formulated in a way that can provide nutrients in balanced concentrations required during the production of a specific crop (Chhibber, 2017). Nitrogen, phosphorous and potassium are the major or macro-nutrients present in inorganic fertilizers and are also known to supply micro-nutrients in much smaller quantities.

**Table 2: Macro- and micro-nutrients provided by fertilizers that are necessary for plant growth (Cheremisinoff, 1997)**

Macro-nutrients		Micro-nutrients
Primary nutrients	Secondary nutrients	
Nitrogen	Calcium	Boron
Phosphorous	Magnesium	Chlorine
Potassium	Sulphur	Copper
		Iron
		Manganese
		Molybdenum
		Zinc

### Nitrogenous fertilizers

Nitrogen is present in three forms in nitrogenous fertilizers:

- **ammonical nitrogen** *viz.*, ammonium sulphate, ammonium chloride
- **nitrate nitrogen** *viz.*, calcium ammonium nitrate (ammonical + nitrate nitrogen are present)
- **amide nitrogen** *viz.*, urea ( $\text{CH}_4\text{N}_2\text{O}$ )

### Phosphatic fertilizers

Phosphate is present in the form of available phosphate *viz.*, single super phosphate (SSP), double super phosphate (DSP) and triple super phosphate (TSP)

### Potassium

Muriate (potassium chloride) and sulphate of potash are general used to meet the requirement of potassium in the soil.

Fertilizers can also be grouped as:

**Straight fertilizers** – In straight fertilizers, only one nutrient is present. A few examples are nitrogenous straight fertilizers *viz.*, urea, ammonium sulphate, ammonium chloride and calcium ammonium nitrate (CAN); phosphatic straight fertilizer: Single super phosphate (SSP), triple super phosphate (TSP).

**Complex or mixed fertilizers**– In complex fertilizers, more than one nutrient is present. e.g., diammonium phosphate (DAP), nitrophosphate (NP) and different blends of NPK fertilizers.

Thus, the role of chemistry is inevitable in manufacturing fertilizers because with the increase in urbanization and a decrease in agricultural land, the use of fertilizers in appropriate quantities has become

an important aspect to increase the yield of crops to counterbalance the loss in agricultural land.

### Chemistry in manufacturing pesticides

Pesticide is a broad term used to refer to the organic, inorganic, synthetic and biological compounds that can either inhibit the growth and development of the pest or kill the pest of all kinds. Based on their chemical composition, mode of action, mode of entry,

time of development and type of pests, pesticides are classified into insecticides (may include insect growth regulators, repellent, antifeedants), acaricides, termiticides, rodenticides, nematocides, molluscicides, herbicides, fungicides, bactericides (Randall et al., 2014). Herbicides are the most extensively used pesticides that alone can account for 80% of all pesticide use (Gilden et al., 2010).

**Table 3: Classification of pesticides based on their chemical composition (Benson, 1969)**

Sl. No.	Pesticide	Examples
<b>A Fungicides</b>		
1	Inorganic compounds containing	Copper, Mercury, Chromium, Zinc, Sulfur, Other metallic compounds
2	Organic compounds	Dithiocarbamates, Phthalimides, Phthalimides, Dodine, Quinones, Pentachlorophenol, Others
<b>B Herbicides</b>		
3	Inorganic compounds	Sodium chlorate
4	Organic compounds	Petroleum fractions, Arsenicals, Phenoxy type (2,4-D; 2,4,5-T; other phenoxy and related compounds), Phenylureas, Carbamate (thiol, N-phenyl), Dinitrophenols, Triazines, Benzoic acids, High bromine content, Phosphorus (aliphatic phosphites, phosphates), Amides, Quaternary salts, Other organics
<b>C Insecticides</b>		
5	Inorganic compounds	Arsenicals - Paris green, Others - NaAlF <sub>6</sub> (cryolite)
6	Botanicals and derivatives	Nicotine, Pyrethrum
7	Biologicals	<i>Bacillus thuringiensis</i>
8	Petroleum	
9	Synthetic organic compounds	Chlorinated: aldrin-toxaphene group, lindane and isomers (BHC) and DDT group Phosphorus (with and without sulfur): aliphatic phosphates and phosphonates, vinyl phosphates, aromatic phosphates and phosphonates, pyrophosphates Carbamate: N-methylcarbamates, N, N-dimethylcarbamate
10	Miticides/ Acaricides	Sulfites, sulfones, sulphides, sulfonates; Dinitrophenols
11	Fumigants	Space and product - HCN, CH <sub>3</sub> Br Soil type - CH <sub>3</sub> NCS, BrCH <sub>2</sub> CH <sub>2</sub> Br
12	Defoliant and desiccants	Phosphites, H <sub>2</sub> SO <sub>4</sub>
13	Rodenticides	Anticoagulants (Coumarins), Other (Fluoroacetamide, 1-Naphthyl thiourea)
14	Other	Plant growth regulators - 1-Naphthylacetic acid Repellents (insects, birds) - allylthiocyanate

Pesticides are intended to serve as potential products that impart protection to plants by minimizing the damages caused by pests and pathogens without compromising the yield and productivity.

### Chemistry in sustainable arable crop protection

Organic chemistry has been the mainstay of crop defense strategies for arable cultivation

and food production for more than half a century. Through maintaining the extracted yield of the world's crops, the management of pathogenic infections, insect pests and weeds has rendered a critical contribution to food production worldwide. Inclusion of these compounds in the integrated pest management system is possible only when they show environment friendly properties along with

high specificity (inhibit the growth of target pest and pathogens) and biodegradable properties. Thus researchers are keen to understand the advances made during the discovery of newer molecules for sustainable crop production and protection by including series of tests to evaluate the toxicological, biochemical and physiological aspects of the compounds (Smith, 2018). This need has arisen due to the multiple factors related to development of resistance in pests and pathogens, pest resurgence, health and environmental hazards caused due to the indiscriminate use of pesticides. Therefore, chemistry has enabled the scientists to discover efficient newer molecules with new mode of actions without upsetting the ecological balance (Smith, 2018 and Godwin et al., 1992). e.g. development of azoxystrobin.

#### **Chemistry in other areas of agriculture**

- **Chemistry in food processing and post harvest management of agricultural produce**

Chemistry plays a vital role in the food processing industry as it deals with various chemical reactions and interactions that occur between biological and non-biological compounds of food (Kumar et al., 2016 and deMan, 1999). By exploiting the advances in chemistry, attempts are being continuously made by the researchers to upgrade the quality (in terms of flavour, taste, appearance and nutritional values) of food products, to counter the effects of deterioration and spoilage within a short period of time as well as to increase the shelf life (Kumar et al., 2016 and Potter & Hotchkiss, 1995). e.g. application of sulphur dioxide in grains helps in keeping the grains fresh and useable for a longer period; use of sodium benzoate and salicylic acid as food preservatives increases the shelf life; development of new generation refrigerants; use of saccharin, sweeteners, enzymes, vitamins, hormones and minerals to enhance the quality of food products; etc. Thus, advancement in chemistry has led to increase in diversity of diet in humans and animals and also availability of food products to a greater extent.

- **Extensive use of plastic pipe in agriculture**

The development of plastic is a contribution made by chemistry. The manufacture of plastic pipes has enabled their usage massively in the agricultural sector for irrigation purpose (Chhibber, 2017).

- **Chemistry in production of chemicals from agricultural wastes**

Advancements in chemistry have played a major role in the development of processes through which conversion of bio-products into bio-energy could be carried out. The residues produced from agricultural wastes are known to have rich sources of bioactive compounds that can be utilized as an alternate source for production of biofuel, biogas and other raw materials (Sadh et al. 2018). Utilization of these products not only helps in maintaining air pollution-free environment but also ensures sustainability in the long run as other natural resources like sources of petrochemical hydrocarbons are present in finite quantities. e.g. development of antioxidants, antibiotics, vitamins, feeds of animals *via* solid state fermentation (SSF) (Bhargav et al., 2008); use of anaerobic digestion (AD); pre-treatment of biomass, hydrolysis and fermentation of enzymes, purification and catalytic conversion of lactic acid to acrylic acid.

#### **CONCLUSION**

The discipline, chemistry has been playing and will continue to play an inevitable role in the agricultural sector as it not only provides innovative ways to produce the crops but also provide remedies to mitigate or limit the potential problems related to various pests and diseases including nutrient deficiencies without hampering the yield, productivity and quality of the crops in an eco-friendly way.

#### **REFERENCES**

- Anonymous. (2019). Importance of agriculture in the national economy. *Environment*, (<https://impoff.com/importance-of-agriculture>).

- Baokar, S., Lahane, S., Taware, G., & Jadhav, R. B. (2018). Role of chemistry in agriculture. *Proceedings of Innopharm3 International: Conference on Academic and Industrial Innovations*, pp. 341.
- Benson, W. (1969). The Chemistry of Pesticides. *Annals of the New York Academy of Sciences*, 160, 7-29.
- Bewick, S., Parsons, R., Forsythe, T., Robinson, S., & Dupon, J. (2017). Introduction to Chemistry. Introductory Chemistry (CK-12). e-book. (<https://chem.libretexts.org>).
- Bhargav, S., Panda, B.P., Ali, M., & Javed, S. (2008). Solid-state fermentation: an overview. *Chem.Biochem. Eng*, 22, 49-70.
- Brown, T.L., Lemay, H.E., Bursten, B.E., & Lemay, H. (1999). Chemistry: The Central Science. Prentice Hall. Ed. 8.
- Bryant, D.A., & Frigaard, N.U. (2006). Prokaryotic photosynthesis and phototrophy illuminated. *Trends in Microbiology*, 14, 488-496.
- Cheremisinoff, P.N. (1995). Industry profile – fertilizers. Waste minimization and cost reduction for the process industries. pp. 222-284.
- Chhibber, V.K. (2017). Role of chemistry in agriculture. (<https://www.bfitdoon.com/blog/role-of-chemistry-in-agriculture>).
- deMan, J.M. (1999). Principles of Food Chemistry. Food Science Text Series. Springer Science. Ed. 3.
- Gilden, R.C., Huffling, K., & Sattler, B. (2010). Pesticides and health risks. *Journal of Obstetric, Gynecologic and Neonatal Nursing*, 39, 103–110.
- Godwin, J. R., Anthony, V. M., Clough, J. M., & Godfrey, C. R. A. (1992). ICIA5504: a novel, broad spectrum, systemic beta-methoxyacrylate fungicide. *Brighton Crop Protection Conf. Pests and Diseases. Brighton, UK*. vol. 1. pp. 435-442.
- Gontard, N., Sonesson, U., Birkved, M., Majone, M., Bolzonella, D., & Celli, A. (2018). A research challenge vision regarding management of agricultural waste in a circular bio-based economy. *Critical Reviews in Environmental Science and Technology*, 48, 614-654.
- Kumar, K., Kumar, R., Kumar, V., & Sagwal, S. (2016). Role of Chemistry in Food Processing and preservation. 5<sup>th</sup> National Conference on Chemical Sciences: Emerging Scenario & Global Challenges (Role of Chemical Sciences to make in India). pp. 64.
- Lamberth, C., Jeanmart, S., Luksch, T., & Plant, A. (2013). Current challenges and trends in the discovery of agrochemicals. *Science*. pp. 341-742.
- Lenntech. (2020). [www.lenntech.com/products/chemicals/water-treatment-chemicals.htm](http://www.lenntech.com/products/chemicals/water-treatment-chemicals.htm).
- Plant, A. (2010). Crop Protection Chemistry: Challenges and opportunities in the 21<sup>st</sup> century. AGROW Silver Jubilee Issue. XI: 600.
- Potter, N.N., & Hotchkiss, J.H. (1995). Food Science, Ed. 5. New York: Champmanand Hall. pp. 24-68.
- Randall, C., Hock, W., Crow, E., & Kesai, J. (2014). Pest Management. National Pesticide Applicator Certification Core Manual (2<sup>nd</sup> Ed.). Washington: National Association of State Departments of Agriculture Research Foundation.
- Reinhardt, C. (2001). Chemical Sciences in the 20<sup>th</sup> century: Bridging Boundaries. Wiley-VCH. pp. 1-2.
- Sadh, P.K., Duhan, S., & Duhan, J. S. (2018). Agro-industrial waste and their utilization using solid state fermentation: a review. *Bioresources and Bioprocessing*, 5, 1-15.
- Smith, K., Evans, D.A., & El-Hiti, G.A. (2008). Role of modern chemistry in sustainable arable crop protection. *Philosophical Transactiond R. Soc. Lond. B. Biol. Sci*, 363, 623-637.