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Growing seed

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Volume 2 – Issue 2
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Contents

AGRIALLIS
Science for Agriculture and Allied Sector: A Monthly e Newsletter
Volume 2 – Issue 2
Online ISSN: 2582-368X
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BIOTECHNOLOGY FOR SUSTAINABLE AGRICULTURE: ENHANCING AGRICULTURAL PRODUCTIVITY AND VALUE-CHAIN ADDITION IN CROPS

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Agriculture has been the backbone of food and nutrient supply not only for human but also for animals directly and indirectly. However agricultural land is continuously constricting and decreased over time due to population explosion since last few centuries. Therefore, global agriculture must have to adopt innovative agricultural practices so that it can supply sufficient and nutrient enriched food for ever growing populations (FAO, 2018). An innovative vision for development of agriculture in the backdrop of international regime, ecological crisis and socio-economical constraints worldwide could truly be derived only from the convergence of agricultural biotechnology with Nano-Science and Bioinformatics. Precision agriculture embodies such a convergence of Bio based technologies. Critically we must seek to blend traditional wisdom with modern tools of biotechnology (Estrada *et al.*, 2017). Aided by the wisdom of sustainable agriculture and the wonders of precision farming, farmers will have a fighting chance to give us daily bread and provide cleaner environment to the future generations.

Major Constraints to Sustainable Agriculture

Sustainable Agriculture can be defined as the management of agricultural resources to satisfy human needs, without compromising the quality of the environment and hampering natural resources. Sustainable agricultural production is hampered by the decline in land and soil productivity as a result of inappropriate soil and water management practices. Since green revolution, huge amount of hazardous agro-chemicals such as fertilizers, pesticides and fungicides are constantly being employed to the soil which are becoming toxic to human, animals or even to other biota (FACTSHEET, 2016). Furthermore, agricultural sustainability requires improved seeds, integrated nutrient and pest management (INPM) practices, tools and machinery. Although these requirements are un-assessable to most resource-poor farmers due to high cost, so scientists have to take forward to resolve these issues to achieve agricultural sustainability in precise manner.

Sustainable Agriculture: Can Biotechnology play a role?

Biotechnology can provide useful products and services for sustainable development of agriculture. The major contribution biotechnology had made in modern agricultural practices is by reducing the use of agro-chemicals, without compromising the productivity needed to feed ever growing population world over with added production and development of biotic and abiotic resistant crops (Estrada *et al.*, 2017). Biotechnology can also supply faster and even more précised diagnostic tool for animal and plant diseases, and through improvements in the supply-chain of livestock fodder and feeds.

Biotechnological Tools and Techniques for Developing Sustainable Agriculture

- **Conventional Plant Breeding**

Since the beginning of agriculture eight to ten thousand years ago, farmers have been altering the genetic makeup of the crops they grow. They manually select the best plants or seeds and saved them for the next year. Early farmers adopted features such as higher yields, faster growth, larger seeds, pest and disease resistance, better fruits set, etc for selection. In the same way, Plant breeding came into existence and found that plants could be artificially mated to improve the desirable trait of interest in the crop plants. Desirable characteristics from different parent plants could be combined in the offspring by cross-pollination. With the gradual development of science of plant breeding in late 20th century, breeders learned better how to select superior parent plants, breed them and improved them as a varieties having desirable traits (Estrada *et al.*, 2017). This has considerably increased the quality and productivity of the plant produce.

- **Tissue Culture and Micropropagation**

Plants usually follow sexual means to reproduce because they have ability to set seeds after flowering and hence create their next generation. Egg cells in the flowers are fertilized by pollen from the stamens (male part) of the flower of the same plant (self-pollination) or another plant (cross). Some plants and trees on the other hand need several years before they flower and set seeds, making plant improvement difficult. Plant scientists have developed the science and art of tissue culture to assist breeders in this task.

- **Molecular Breeding and Marker-Assisted Selection**

For developing new varieties, conventional breeding requires multi-step process and can take 12-15 years. However, by adopting molecular breeding approaches assisted with agricultural biotechnology tools and techniques, the breeders can shortened the time upto 7-10 years to design new crop varieties (Estrada *et al.*, 2017). The most acceptable tools, which make it easier and faster for scientists to select plant traits is called marker assisted selection (MAS). The genes or QTLs associated with the complex trait such as flower color, crop yield, starch content and other quality traits can be easily identified from the plants in early stage of growth without significant influence of genotype to environment interactions, thus minimizes the time, skill and cost taken for selection and other breeding process.

- **Genetic Engineering and GM Crops**

Over the last few decades, the agricultural biotechnology has grown rapidly due to the increasing knowledge about the DNA as the chemical messenger of the genome. Genetic engineering or often gene technology is one of the modern biotechnology tools that are frequently used in agricultural science for crop improvement. This involves the manipulation of genetic makeup of plants or even animal to design chimeric organism having altered genomic constitution (Estrada *et al.*, 2017). By manipulation of genetic makeup of plants, the desirable genes can either transferred across the species or, even silenced the effect of undesirable genes. These exertions limit the crop improvements by means of plant breeding, but because of some misconception about the biosafety issues, consumer's acceptance of GM crops is also need to be resolved.

Conclusion and Future prospects

New agricultural technologies, in general, need to cover two societal requirements-ensuring a safe, nutritious, and affordable food supply for the ever growing mouths and also minimize the biosafety concerns and other associated environmental issues. Advances in plant breeding, agrochemical research and agriculture and farm mechanization will be required to meet world food production needs. Agriculture biotechnology complements breeding efforts by escalating the germplasm conservation and diversity of genes needed for

Volume 2 – Issue 2
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crop improvement within a shortened time. Thus in view, the article focuses on the biotechnological approaches for building a new tool which can significantly impact crop productivity in a sustainable and environmentally sound manner.

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Science for Agriculture and Allied Sector: A Monthly e Newsletter
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www.agriallis.com

CARBON SEQUESTRATION THROUGH ORGANIC FARMING

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Carbon sequestration in the agriculture sector refers to the capacity of agriculture lands process by which carbon is fixed from the atmosphere via plants or organic residues and stored in the soil. Soil has capacity to store around 20 Pg carbon in 25 years, which is more than 10% of anthropogenic emissions (FAO). Carbon are continuously move in carbon cycle, but over main aim is more carbon sequestration and store in stable form in soil.Forests and stable grasslands are referred to as carbon sinks because they can store large amounts of carbon in their vegetation and root systems for long periods of time. In soil, there are basic three forms of carbon that may be present: 1) Element C, 2) Inorganic C,3) Organic C.There are three ways that carbon can be sequestered: 1) Terrestrial sequestration: in plants and soil, 2) Geological sequestration: underground, 3) Ocean sequestration: deep in ocean.

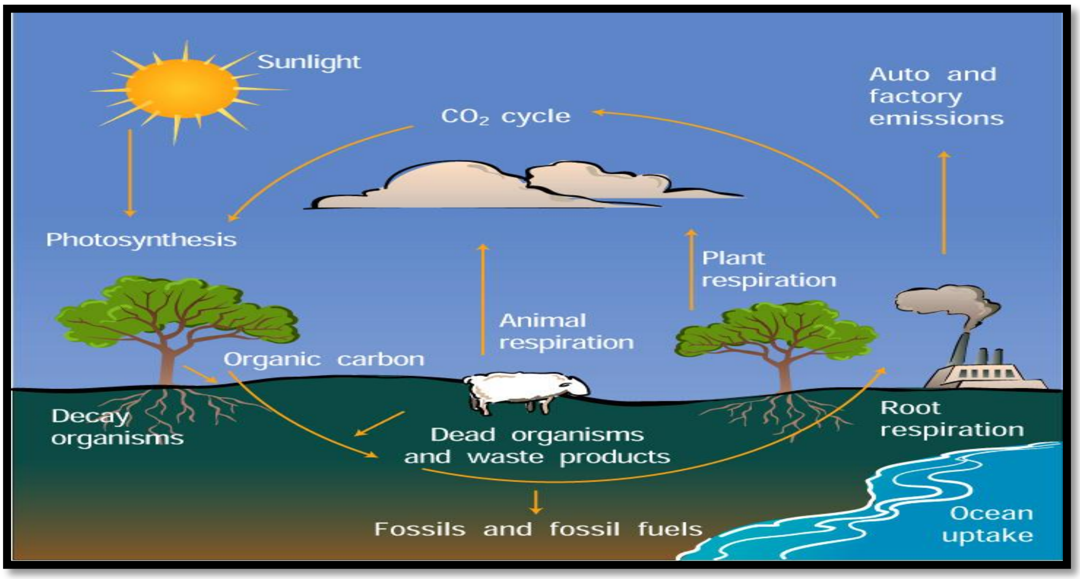

Fig.1 Carbon cycle (Source: https://eo.ucar.edu/kids/green/images/carboncycle.jpg)

The main causes of soil organic carbon depletion are soil erosion, residue burning, land use change, intensive cultivation, nutrient imbalance, low productivity and overgrazing. Organic farming is the way that we can minimize organic carbon depletion in soil through

Volume 2 – Issue 2
Online ISSN: 2582-368X
www.agriallis.com

carbon sequestration. Organic farming is a system which avoids or largely excludes the use of synthetic inputs (such as fertilizers, pesticides, hormones, feed additives *etc*) and to the maximum extent feasible rely upon crop rotations, crop residues, animal manures, off-farm organic waste, mineral grade rock additives and biological system of nutrient mobilization and plant protection. Total areas under organic agriculture land in india is 1.18 mha. The major states in india are MP, MH, UP, GJ and Odisha combined share of 90% organic food market in india (WOA, 2017).

Why carbon sequestration needed?

- **Soil:**
  - Increase soil fertility
  - Improve physical, chemical and biological properties
  - Rehabilitation of degraded land
- **Crop:**
  - Enhancing crop productivity
  - Increased income of farmers
  - Food security
  - Increase in use efficiency of inputs
- **Environment:**
  - Reduced GHGs emission
  - Enhanced soil C sink
  - Decrease in pollution

How organic farming helps in carbon sequestration?

- Organic farming is complimented the carbon sequestration because it focus on sustainability without using synthetic fertilizers, pesticides etc.
- Organic mulching refers to covering the soil with any organic matter such as applying compost or farm yard manure over the soil surface followed by adding a layer of dry organic matter over it.
- This compost contains aligned beneficial microbes, where the dry matter is rich in carbon and the green matter is rich in nitrogenous substances. When decomposition of these components takes place the carbon nitrogen ratio in the soil becomes 10:1, ideal for the proliferation of microbes. This type of farming practices not only improve the soil fertility but also increase farmers’ income.

- Hence, we can say organic farming is one of the best ways of improving soil fertility which co-benefited the sequestration of carbon from atmospheric CO_2.

Organic Farming management practices to increase soil organic carbon

- Tillage and residue management:Conservation tillage practices recorded significantly higher soil organic carbon content and soil carbon sequestration at 0-15 cm and 0-30cm depth as compared to conventional tillage with and without crop residue (Kumar and Babalad, 2018). Zero tillage with residue retention increase soil organic carbon and microbial biomass carbon. The compost, paddy and wheat straw and maize stover used as mulch for improving soil organic carbon content.
- Nutrient management: The nutrient management practices include manure and compost, green manure, legume integration and microbial fertilizers.Mishra (2015) reported that application of FYM + vermicompost 2t/ha (split) recorded higher soil organic carbon, soil carbon sequestration rate.Salahin *et al.* (2013) suggested that green manure crop (*Sesbania aculeate*) increase organic carbon, porosity, rice and wheat yield as compare to rest of treatment.

Fig.2 Farms planting into a no-till system

(Source: https://fyi.extension.wisc.edu/foxdemofarms/conservation agriculture/minimal-soil-disturbance-conservation-tillage/)

Conclusion

Organic farming practices are capable of enhancing soil properties and serving as a potential sink of atmospheric carbon dioxide sequestrated in soil through zero tillage, minimum tillage with crop residue management and application of organic amendments helps

Volume 2 – Issue 2
Online ISSN: 2582-368X
www.agriallis.com

in sequestering carbon in surface soil, may have also positive effect on soil fertility and increased crop yield.

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AGRIALLIS
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www.agriallis.com

STEVIA REDAUDIANA IN THE INDIAN HORTICULTURE

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The Stevia Redaudiana is the natural sweetener commonly known as sweet leaf or sugar leaf belongs to family Asteraceae (Genus Jan, 2003). It is an herb whose plant size is 60-120cm, whereas that of leaves is 3-4 cm. It is a rich source of sweetener and the best substituent of sugar. The leaves are hairy on the upper surface while it is woody on the lower surface. The herb after the hoar grows in spring. The flowers are whitish and come in the month of July to September. There are 240 known species of Stevia. Of these, 18 species were found to be used after further processing for the sweetening (Soejarto *et al.* 1982). The leaves are 30 times and its entrants are 300-400 times sweeter than sugar and are long-lasting. It is rain resistant horticultural crop plant that can be grown in the rainfed, water lodging or even in less fertile soil. It can be only damaged by over or heavy rain. Winter is the best growing season but in the northern states of India due to longer exposure to summer and hot wind, the concentration of sugar increases optimum temperature 10-30 degrees centigrade with 65-85% humidity and 5.5 to 7.5 pH soil.

The whole chemical composition of this Plant is not known but some emeritus had revealed certain chemically active glycoside and its derivatives such as glucoside-A, rebaudioside A-E but the economic value is returned by the enrichment as well as stabilization of the two main compounds i.e., stevioside (10-20%) in the Stevia leaves which is stable at 100-degree centigrade whereas Rebaudioside-A (1-37%) which is stable at 120-degree centigrade. Due to its stability at a higher temperature, Stevia is a thermally stable compound. Chemical composition which is known mostly belongs to diterpene which is immobilized or inter-converted into the different chemical compound, zero-calorie and hygroscopic in its natural condition (Kinghorn *et al*. 1984, Shibata *et al.* 1995, Ngowatana 1997, Kumar *et al*. 2007, Soejarto *et al*. 1982). The solution of stevia has been found to be neutral (i.e., stevia + distilled water in various proportions) therefore, it maintains the

Volume 2 – Issue 2
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www.agriallis.com

chemical and ionic equilibrium of the corresponding medium. The plant of Stevia has a saturated amount of meditational values as it is used for the curing of heart disease, dysentery, asthma, high blood pressure, etc. Besides this, it also acts as an antibacterial for the mouth and pampers on the face. It is also used in the preparation of different daily needs such as chewing gum, mouth wash, toothpaste, and many other herbal tea powders. It also improves insulin sensitivity and can be used for a dietary supplement. Along with these it can be utilized as food products such as sauce, pickles, ice-creams, ice-cakes and also in pharmacculated formulae due to processing non-farming properly.

Apart from this, Stevia is rich in protein, various nutrients like magnesium, niacin, riboflavin, zinc, chromium, selenium, calcium and phosphorous. Stevia dried leaves when are used in powdered form, it not only helps in increasing the natural sweetness but also help in regenerating the pancreatic glands. It can acts as a ray in the dark for diabetic patients. The dried leaves are considerately sweeter than fresh leaves and can also be used as an aid in the tea powder. Stevia extract is so extensively sweet that a pinch is generally recommended to use and the remaining is being refrigerated.


(Source Figure: reports of agri-farming, 2018)

The chemical compounds which are fairly present in adequate amount are generally hygroscopic in nature (Ngowatana, 1997). Pederson, 1987 reported the chemical composition and comparative study between sugar leaf and extract of the Stevia which is tabulated as follows:

Volume 2 – Issue 2
Online ISSN: 2582-368X
www.agriallis.com

Table 1: Elemental composition of Stevia

Sample number	Elements	Constituent Value (%)
1	Al	0.0072
2	Mn	0.0147
3	Ash	6.3
4	P	0.318
5	b-carotene	0.0075
6	K	1.78
7	Ca	0.544
8	Protein	11.2
9	Cr	0.0039
10	Se	0.0025
11	Co	0.0025
12	Si	0.0132
13	Fat	1.9
14	Na	0.0892
15	Fiber	15.2
16	Tin	0.0015
17	Fe	0.0039
18	Vitamin	0.011
19	Mg	0.349
20	Water	82.3

Table 2: Comparative Study

Granulated sugar	Stevia leaf powder	Stevia white extract
1 Teaspoon	1/8 teaspoon	Dust
1 TableSpoon	3/8 teaspoon	1/2 Pinch
1/4 cup	1/2 teaspoon	1/8 Pinch
1/2 Cup	1 Table Spoon	1/8 teaspoon
1 Cup	2 Table Spoon	1/4 teaspoon

Source: Pederson, 1987, Approximate composition of Stevia rebaudiana Bertoni Nutr Herbol 18:377–380.

Volume 2 – Issue 2
Online ISSN: 2582-368X
www.agriallis.com

The scenario of Stevia cultivation

In the day to day life, people use low-calorie food results in the overutilization of calories and thus cause hazards to the health and gradually create serious health problems like diabetes, heart disease, dysentery, asthma, high blood pressure, etc. The artificial marketed products are used to reduce the calories of the day which would cause long term side effects creating different problems. Stevia leaves widely grown for its sweetening products, soft drinks, and candies especially in Japan (Soejarto *et al.* 1982).

Stevia is the native plant of tropical and subtropical regions of North and South America. Nowadays, it is grown and distributed in various different parts of a country widely such as Brazil, Columbia, Venezuela, etc. for natural therapy (Jeppesen *et al.* 2000, Suttajit *et al.* 1993). In countries like Venezuela, it is used for the last 1500 years. A good marketed price with good Stevia cultivation is developed domestically as well as internationally. Stevia in India is cultivated in a different part of the country such as Gujarat, Maharashtra, Rajasthan, Punjab, etc. Its distinctive flavor blends with aromatic species such as Cannon & Ginger. All new and latest techniques of farming are used in its cultivation.

Management practices in the cultivation of Stevia

Stevia is propagated by stem cutting and by seeds. The seed rate of stevia is generally recommended at 400-450gm/ha. Due to herbaceous nature, it has a tendency to germinate 100%. Propagation with seeds is cost less but time-consuming process while that of stem cutting cost-effective but grows very severely. Therefore, the development of a new and better variety of stem cutting by biotechnical process increases at an accelerating rate.

Plowing preparatory tillage is required before sowing. The manure and fertilizers are sprinkled, mixed with the soil before the formation of the rows. It lives well in nitrogen-deficient soils. Plants are prepared 10-12 days before sowing into different rows into the field. Its sowing should be followed in the month of March- April for summer months while June-July in winter months. The seeds are to be sown at a distance of 45cm*45cm in summer and 45cm*30cm in the winter. As a vegetable, Stevia also requires organic manure to be enriched. During the cultivation of Stevia, the use of insecticide and pesticide is strictly prohibited. It cannot survive in the drought and frost condition hence, irrigation is done just after sowing and second irrigation are done 2-3 days after sowing however irrigation is not required in the rainy season. The crop should be kept always free from the weed therefore proper training and pruning is required. In general practice, 4-5 training is required during its early stages to keep away from the weeds. Mulching practice gives the best result. Mulching with the rice husk seems to give the best result than any other mulching material. The plants are practiced in two ways i.e. sympodial and monopodial ways. In the sympodial approach, the buds are broken just 20-25 days after planting to increase the number of branches while for the quality we use monopodial type cultivation.

The plants should be cut 10-15 cm above the ground so that it should be followed with the difference of 3 months of sowing. The second harvesting should be done in between 60-70 days from the first cutting. If the practice is delayed then it should be delayed for harvesting for 3-4 months. It is the perennial type crop which gives the cultivation for 4-5 years. 3-4 times of plant cutting is required in a year. Maximum leaves are obtained in the 3rd and 4th year of sowing. The yield coming out from the practice is 20-30 tones. This gives 4-5 tones of dry matter. Total dry leaves obtained first, the second, third and fourth year is 17, 20, 23, 25 tons per hectare.

Statistically, the production of Stevia is low corresponding to the present demanding scenario. Thus, various government societies and non-government organizations such as the Indian Institute of Vegetable Science (Varanasi), Hahnemann Charitable Mission Society (HCMS, Jaipur) organizes training programs to enhance the production of Stevia Cultivation. The attendee could be individuals, Co-operates, entrepreneurs and rural farmers whoever wants to cultivate.

Conclusion

Stevia is a natural origin, zero-calorie, sustainable sweeter. The safety of high purity stevia extract for human consumption has been established through rigorous peer-reviewed research. All major global regulatory organizations, including the Food and Agriculture Organization/World Health organization’s Joint Expert Committee on Food Additive (JECFA), the European Food Safety Authority (EFSA), the Food and Drug Administration (FDA), and Food Standards Australia New Zealand (FSANZ), have determined high purity Stevia extract to be safe for use by the whole family.

Volume 2 – Issue 2
Online ISSN: 2582-368X
www.agriallis.com

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AGRIALLIS
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QUALITY PROTEIN MAIZE: A WONDERFUL CEREAL

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Maize (*Zea mays* L.), an American word for corn, literally means "that which sustains life." Maize is emerging as an important cereal crop in the world agricultural economy as food, feed, and industrial raw material after wheat and rice, which is considered as "Queen of cereals," due to the high productiveness, easy to process, low cost than other cereals (Jaliya *et al*., 2008), provides nutrients for humans and animals, serves as basic raw materials for production of starch, oil, alcoholic beverages, and more recently fuel (Punita, 2006). Maize is a valuable source of carbohydrates, fat, protein, some important vitamins and minerals and in spite of several important uses, it has an inbuilt drawback of being deficient in two essential amino acids, *viz*., lysine and tryptophan. This leads to poor protein utilization and low biological value of traditional maize genotypes. The low protein and unbalanced amino acid content in maize cause protein deficiency diseases like kwashiorkor and malnutrition. To overcome this problem and to minimize the prevalence and persistence of malnutrition in developing countries, breeders have modified maize to produce a vitreous endosperm resembling that of conventional maize at Purdue University, USA, in 1963 and named as quality protein maize (QPM) by incorporating opaque-2 gene, which is particularly responsible for enhancing lysine and tryptophan content of endosperm protein. QPM looks and tastes like normal maize with the same or higher yield potential, but it contains nearly twice the quantity of essential amino acids, lysine, and tryptophan which makes it richer in quality proteins. QPM combines the nutritional excellence of opaque-2 maize (whose protein content is twice that of normal maize) with the kernel structure of conventional maize varieties (Vassal *et al*., 1993). Hence, the cultivation of QPM provides an opportunity for the farmers to produce nutritionally superior maize grains, where maize is a staple food and potential source of proteins in many developing countries of Latin America, Africa, and Asia.

Volume 2 – Issue 2
Online ISSN: 2582-368X
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History

Genetic variability for most traits in maize is incredibly high and amenable to enhancements. Attempts to improve protein content began towards the latter part of the nineteenth century. Prior to the 1960s, efforts were rather limited to only screening elite maize germplasm and accessions to identify genotypes superior for this trait. Since no specific gene(s) conferring enhanced nutritional value was identified at that time, an improvement strategy involving recurrent selection could not be easily implemented. The lack of a simple genetic system also precluded the use of a straight forward back cross-program. Thus, protein quality remained more of a concern, with no immediate solutions in sight and no action-oriented strategies deployed to resolve the issue. In the early 1960s, scientists manifested a special interest in the search for gene mutants that could provide better quality protein in the maize endosperm. In 1963, researchers at Purdue University, USA, discovered that a mutation, designated opaque-2, made grain proteins in the endosperm nearly twice as nutritious as those found in normal maize (Mertz *et al*., 1964). The opaque-2 mutation was first described by Jones and Singleton in the early 1920s, but the nutritional significance of the mutation was first discovered by Mertz and co-workers (Mertz *et al*., 1964; Nelson *et al*., 1965). This was soon followed by the discovery of another mutation, floury-2 (fl2) that also has the ability to alter endosperm nutritional quality (Bjarnason and Vasal, 1992). These mutations, which derive their names from soft, floury/opaque endosperm, alter the amino acid profile and composition of maize endosperm protein and result in a two-fold increase in the levels of lysine and tryptophan in comparison with the normal genotypes. In addition, other amino acids such as histidine, arginine, aspartic acid, and glycine show an increase, while a decline is observed for some amino acids such as glutamic acid, alanine, and leucine. The decrease in leucine is considered particularly desirable as it makes leucine–isoleucine ratio more balanced, which in turn helps to liberate more tryptophan for niacin biosynthesis, and thus, helps to combat pellagra. The QPM research was started long back during the 1970s, but gained momentum during the 1990s with continuous breeding efforts on the development of high yielding hard endosperm modified Opaque-2 maize germplasm by International center for maize and wheat improvement (CIMMYT). The Directorate of Maize Research (DMR), New Delhi developed the first QPM composite variety Shakti-1 with 0.63 percent tryptophan in the year 1997. The QPM research gained further momentum by the launch of the National Agricultural Technology Project (NATP) on QPM in 1998 by ICAR. Chaudhary Charan Singh Haryana

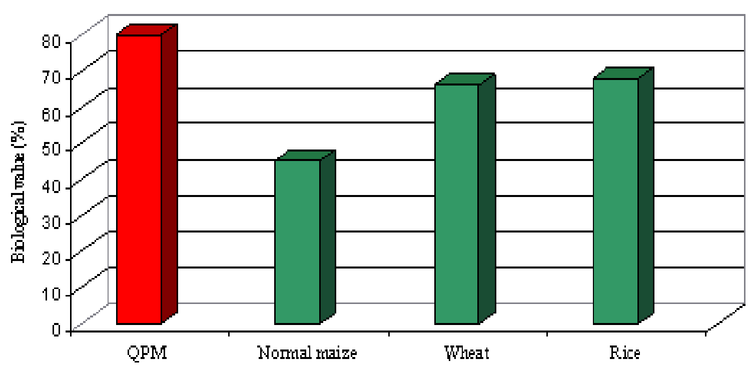
Volume 2 – Issue 2
Online ISSN: 2582-368X
www.agriallis.com
AGRIALLIS
Science for Agriculture and Allied Sector: A Monthly e Newsletter

Agricultural University, Karnal released QPM single cross hybrid, HQPM-1 which is the first yellow grain QPM single cross hybrid released for its cultivation across the country.

Nutritional superiority of QPM

The nutritional benefits of QPM for people, who depend on maize for their energy and protein intake, and for other nutrients, are indeed quite significant. Mertz *et al*. in 1964 first reported that the lysine content in QPM was 3.3 to 4.0 g per 100 g of endosperm protein, which was more than twice that of normal maize endosperm (1.3 g lysine per 100 g endosperm protein). The studies indicated that the QPM protein contains, in general, 55% more tryptophan, 30% more lysine, and 38% less leucine than that of normal maize. Besides protein quality, another important factor is 'biological value', which refers to the amount of absorbed nitrogen needed to provide the necessary amino acids for different metabolic functions. The biological value of normal maize protein is 45%, while that of QPM maize is 80%. The other nutritional benefits of QPM include higher niacin availability due to a higher tryptophan and lower leucine content, higher calcium and carbohydrate (Graham *et al*., 1980), and carotene utilization (De Bosque *et al*., 1988). QPM can also be used as an ingredient in the preparation of composite flours to supplement wheat flour for bread and biscuit preparation.

Biological value of different cereals



QPM in livestock feeds

Worldwide, about 70% of the maize produced is utilized in livestock feed. Fifty percent of the commercial poultry feeds consist of maize. In addition synthetic amino acids mainly lysine and methionine which are imported, must be added to poultry feed. Quality protein maize is superior to normal maize in its amino acid balance and nutrient composition and improves the performance of livestock and poultry. It is more economical to use diets incorporating QPM as it can lead to progressive reductions in the use of synthetic feed additives. QPM will reduce the use of fish meal and imported synthetic amino acids. This

Volume 2 – Issue 2
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www.agriallis.com

will reduce the cost of the feed, making the feed more profitable. It will also improve the commercial poultry industry which will provide a sustainable market for QPM grain in the region.

Value addition

Value addition is important in increasing the shelf life and usefulness of QPM products, improves taste, increases uniformity, and reduces bulkiness hence easier to transport and store. It also guarantees confidence and satisfaction/visual consumers. Hence, value addition requires creating awareness for the market to accept/demand the product at the value and should be profitable. Processing has the potential for enabling QPM to attain an industrial status that would help to create more employment, improve nutrition and increase incomes for QPM farmers. QPM processing can be achieved through milling, boiling, roasting, deep-frying, baking, cooking, steaming, fermentation, extrusion, and enzymatic processes.

Processing of QPM product values includes milling as straight flour; composite flour/enriched flour; packing and labeling; flour fermentation and manufacture of alcoholic products; starch and glucose manufacture; and manufacture of animal feed.

QPM food processing facilitates eating, easy digestibility, easy absorption and utilization by the body systems. The following QPM products can be produced, marketed and utilized: QPM flour; QPM oil; QPM snacks such as cakes, biscuits, bread, chapatis, cookies, and cornflakes. QPM products like porridge mix flour recommended for feeding children who are malnourished under the age of five. Also, the composite flour is recommended for weaning children and lactating mothers.

QPM single cross hybrids released in India

Single cross hybrid	Average yield (q/ha)*	Maturity (days)**	Protein content (%)	Tryptophan content (%)	Grain color	Area of adaptation
HQPM-4	67	90	9.0	0.07	Yellow	Across the country
HQPM-7	65	90	9.8	0.07	Yellow	Peninsular India
Vivek QPM-9	45	75	9.2	0.07	Yellow	Himalayan belt
HQPM-5	65	88-90	10.15	0.07	Light- orange	Across the country
HQPM-1	60	88-90	10.09	0.08	Yellow	Across the country
Shaktiman-4	60	95	10.29	0.07	Orange- yellow	Bihar
Shaktiman-3	60	95	8.86	0.06	Orange- yellow	Bihar
Shaktiman-2	60	95	9.27	0.07	White	Bihar

*Yield during *Kharif* season, **During *Kharif* season

Conclusion

The strategy used by the CIMMYT researchers in developing QPM has proved to be successful. The award of the prestigious 'World Food Prize' in the year 2000 to Surinder K. Vassal and Evangelina Villegas is recognition of an outstanding example of interdisciplinary teamwork of the CIMMYT researchers and signifies the relevance of QPM to millions of people across the world. QPM is now of major interest to breeders, geneticists, seed producers, and the industry, as its large scale production promises to offer significant benefits. Dedicated efforts are required for better public awareness and dissemination of QPM technology, particularly in economically deprived regions where maize is used for food and feed purposes, and complementary sources of proteins are either scarce or unaffordable. With the power of genomic technologies now available, and likely to be further developed, it is possible to effectively complement the breeding efforts, provide greater thrust to the QPM and derive significant nutritional and economic benefits for the society.

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STUBBLE BURNING: A MAJOR CAUSE FOR AIR POLLUTION

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India being an agrarian country generates a large quantity of agricultural wastes. Every year large quantities of crop residues are generated, in the form of cereal straws, woody stalks, and sugarcane leaves during harvest periods. Some portion of these residues are used as animal feed, thatching for rural homes, residential cooking fuel and industrial fuel. However, a major portion of the crop residues is not utilized and left in the fields. The disposal of such a large amount of crop residues is a major challenge. To clear the field rapidly and inexpensively and allow tillage practices easily, the crop residues are burned *in situ.* Farmers opt for burning because it is a quick and easy way to manage the large quantities of crop residues and prepare the field for the next crop well in time. Farmers especially in the northern belt of India, practice stubble burning to utilize the period left between two growing seasons for growing leafy vegetables to encash higher economic returns. Stubble burning is the deliberate setting fire to the straw stubble that remains after paddy, wheat, and other grains have been harvested. Stubble is nothing but the left-over crop residue. It is the biomass produced as by-products from harvesting and processing of agricultural crops. In north India, stubble burning is a practice of removing paddy crop residues from the field for sowing next crop viz. wheat. Where 'combine harvesting' method is applied and their Stubble burning becomes essential because combine harvester leaves crop residue behind. These residues put a burden on farmers back because these residues are not so useful for the farmer and there is pressure on the farmer to sow the next crop in time. Therefore, they clear the field by burning the stubble. Stubble burning is a global phenomenon and can be an important contributor to poor air quality worldwide. This practice was widely carried out across the world until well into the 1990s, until most governments outlawed it, including ours.

Stubble burning contribute towards the emission of greenhouse gases (CO2, N2O, CH4), air pollutants like (CO, NH3, NOx, SO2, NMHC, volatile organic compounds), particulates matter and smoke thereby posing threat to human health.Stubble burning not only

Volume 2 – Issue 2
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www.agriallis.com

leads to pollution but also results in loss of nutrients present in the residues as well as in the soil. The entire amount of C, approximately 80–90% N, 25% of P, 20% of K, and 50% of S present in crop residues are lost in the form of various gaseous and particulate matters, resulting in atmospheric pollution. According to different studies, the residues of paddy and wheat crops are major contributors to the total stubble loads in India. In India, about 2.5 million farmers in the Indo-Gangetic plains grow two crops a year—paddy and wheat. Paddy is planted in such a way that its water requirements are met from the monsoon rain, and the fields are cleared within a short period of 10 to 20 days, for the cultivation of wheat. A convenient and easy way to get rid of grass and hay left behind by paddy cultivation is to burn them. However, this practice contributes to air pollution in cities like Delhi, where the air quality is the worst of any major city in the world.

Stubble burning in India

India, with 17 percent of the world population and an agrarian background generates large volumes of food grains such as rice and wheat for domestic consumption as well as for export. According to the Directorate of Economics and Statistics, in 2017–2018, India generated 99.7 Mt of wheat and 112.9 Mt of rice. Of the various crops grown, mostly crop residue of rice, wheat and sugarcane are being burnt.

Jain *et al.* and the Intergovernmental Panel on Climate Change (IPCC) found that the highest contribution of residue burned on the farm is from the states of Uttar Pradesh, followed by Punjab and Haryana. According to IPCC, over 25 percent of the total crop residues were burnt on the farm. Jain *et al.* also reported that the amount of crop residue burned ranged from 8–80 percent for paddy waste across all states. Among different crop residues, the major contribution was 43 percent of rice, followed by wheat around 21 percent, sugarcane 19 percent and oilseed crops around 5 percent.

The Ministry of Agriculture attributes the increase in on-farm crop residue burning is due to a shortage of human labor. Saini *et al.* (2014) observed that 80 percent of the crop residue burning took place during the post-harvest period of April-May and November-December. The reason behind this stubble burning is the cropping patterns used to ensure higher economic returns which leave limited time between two crop cultivations. Some farmers even grow three crops a year with a short gap between harvesting and sowing.

Volume 2 – Issue 2
Online ISSN: 2582-368X
www.agriallis.com

On December 10, 2015, the National Green Tribunal (NGT) had banned stubble burning in the states of Haryana, Punjab, Uttar Pradesh, and Rajasthan. As per section 188 of the IPC and Air and Pollution Control Act of 1981 crop residue burning is a crime. However, there is a lack of strength in its implementation from the government side. The Delhi high court had also ordered against burning residues, while the Punjab government imposed a penalty of Rs 73.2 lakh farmers in 2016 for the burning of crop residue. Although the actual amount of fines charged was not available; farmers continue to burn residues every season — this making both the soil and air poisonous. In addition to wheat and paddy, sugarcane leaves are most commonly burnt. According to an official report, more than 500 million tonnes of crop residues are produced annually in the country, among these cereal crops (rice, wheat, maize, and millets) account for 70 percent of the total crop residue. Of this, 34 percent comes from rice and 22 percent from wheat crops, most of which is burnt on the farm. According to an estimate, every year Punjab alone produces around 23 million tonnes of paddy straw and 17 million tonnes of wheat straw annually of which 80 % of paddy straw (18.4 million tonnes) and almost 50 % wheat straw (8.5 million tonnes) produced in the state is being burnt in fields. Almost whole of paddy straw, except Basmati rice, is burnt in the field to enable early sowing of next crop.

Instead of burning the stubble, it can be used as feed for animals, as bedding material for animals, as compost manure, for roofing in rural areas, biomass energy, bio-thermal power plants mushroom cultivation, packing materials, fuel, paper, bio-ethanol, and industrial production, etc.

Environmental and health risk

A study estimates that crop residue burning released 149.24 million tonnes of carbon dioxide, over 9 million tonnes of carbon monoxide, 0.25 million tonnes of oxides of Sulphur, 1.28 million tonnes of particulate matter and 0.07 million tonnes of black carbon. These pollutants are directly contributing to environmental pollution, and are also responsible for the melting of Himalayan glaciers and for the haze in Delhi. The heat resulting from burning paddy straw penetrates 1 centimeter deep into the soil, elevating the temperature to 33.8 to 42.2 degrees Celsius. This heat resulting from stubble burning kills the bacterial and fungal populations which are essential for fertile soil. Stubble burning also causes damage to other micro-organisms which are a friendly pest that is present in the upper layer of the soil as well as its organic quality. Due to the loss of these ‘friendly’ pests, the wrath of ‘enemy’ pests has

Volume 2 – Issue 2
Online ISSN: 2582-368X
www.agriallis.com

increased and because of this crops are more prone to diseases. The soluble capacity of the upper layers of soil also decreases. According to a report, one tonne of stubble burning leads to a loss of 5.5-kilogram nitrogen, 2.3 kg phosphorus, 25 kg potassium and more than 1 kg of Sulphur and all soil nutrients, besides organic carbon. Burning leads to a rise in ground temperature, as a result, the soil dries up, necessitating additional water for irrigation. Livestock, too, is impacted by crop burning. It has been found that milk production falls up to 50% during the two months of stubble burning.

A study conducted by Gupta in 2016 showed that 84.5 percent of people were suffering from health problems due to the increased incidence of smog. 76.8 percent of people expressed irritation in eyes, 44.8 percent noted irritation in the nose, and 45.5 percent reported irritation in the throat. Another study by the Institute for Social and Economic Change, Bengaluru, founded that every year in rural Punjab people spends Rs 7.6 crore on treatment for ailments caused by stubble burning. During 2017 one in eight deaths in India was due to air pollution, which contributes to more disease burden than tobacco use. The practice of stubble burning around October raises the concentration of particulate matter (PM) in the air to 1,000 micrograms per cubic meter.

This particulate pollution in Delhi's air spikes 20 times above safe levels (World Health Organization).Every year September and October happen to be the time when acute respiratory infections peak in North India. The risk of getting a respiratory infection goes up by thrice as much as any other time of the year.

Alternatives to stubble burning

1. **Farmers can manage crop residues effectively by employing agricultural machines like:**
    - Happy Seeder(used for sowing of the crop in standing stubble)
    - Zero till seed drill (used for land preparations directly sowing of seeds in the previous crop stubble)
    - Baler (used for the collection of straw and making bales of the paddy stubble)
    - Rotavator (used for land preparation and incorporation of crop stubble in the soil)
    - Paddy Straw Chopper (cutting of paddy stubble for easily mixing with the soil)
    - Reaper Binder (used for harvesting paddy stubble and making into bundles)

Volume 2 – Issue 2
Online ISSN: 2582-368X
www.agriallis.com

2. **Technological Interventions like:**

- Retention of Crop Residue as Mulch and Incorporation of in soil.
- Use of crop residue for compost/vermicompost/FYM.
- Crop residue utilization for Mushroom Cultivation.
- Incentivize the purchase of improved machinery to ensure minimum leftover of crop residue.
- Promotion of Custom Hiring/ Agriculture Service Centers.
- Improvement in combine harvester for In-situ management and other mechanisms for collection of crop residue.
- The government should Involve or invite benefiting industries like the cement industry to collaborate in husk/hull or stubble collection to use it proficiently.
- Inviting packaging industries to collect stubble to make packaging boxes that are more environmentally friendly than other non-disposable materials like thermocouple and plastic.

3. Diversified Uses of Crop Residue:

- Use in Power Generation, production of cellulosic ethanol in PPP mode.
- Use of Crop Residue for paper/board/panel and packing material.
- Promotion of collection of crop residue for feed bricks making and its transport to fodder deficient areas.
- Decomposing stubble in the farm field and turning it into useful manure.

Conclusion

Stubble burning is a hot topic at the present time, especially during a time of wheat and rice harvesting. There is no doubt that smoke from burning crop residues affects people's health, road safety, and the environment. Therefore, farmers need to be educated about the ill-effects of crop burning and proper monitoring and regulations should be enforced through government policies. It is the farmer's responsibility to ensure that burning is conducted legally and safely and that the smoke does not cause problems that type of knowledge and awareness is required. Awareness about the negative impacts of stubble burning and the importance of crop residues incorporation in the soil must be created among the farming communities for maintaining sustainable agricultural productivity. An all-round aggressive approach is needed on behalf of the government, scientists, and farmers in the form of adoption of 'straw management technologies.

Volume 2 – Issue 2
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