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REVIEW PAPER

Ecological Aspects of Crop Production in Relation to Integrated Nutrient Management – An Overview

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ABSTRACT

The principles of crop ecology provide valuable information onto optimizing agricultural practices and improving crop productivity. Ecological management of the crop environment focuses on creating a balanced and diverse ecosystem that promotes natural pest and disease control while minimising the use of chemical inputs or enhancing the use of integrated Nutrient Management. Agriculture is built upon fertile soil, a favorable climate, ample freshwater, a diversity of plant and animal species, and the skills and labor of farmers and farm workers. These are the ecological foundations of our food system. They are also endangered by depletion, disruption, or trough diseases. Finding ways to better preserve the health of agricultural ecosystems is key to the long-term sustainability of our food supply. The increasing food demands of a growing human population and the need for an environmentally friendly strategy for sustainable agricultural development require significant attention when addressing the echological issue of enhancing crop productivity. Here we discuss the role of integrated nutrient management (INM). This review examines the concepts, objectives, procedures and principles of INM. A comprehensive literature search revealed that INM enhances crop yields by 8–15 % compared with conventional practices, increases water-use efficiency, and the economic returns to farmers, while improving grain quality and soil health and sustainability. Model simulation and fate assessment further reveal that reactive nitrogen (N) losses and GHG (greenhouse gas) emissions are reduced substantially under advanced INM practices. Lower inputs of chemical fertilizer and therefore lower human and environmental costs (such as intensity of land use, N use, reactive N losses and GHG emissions) were achieved under advanced INM practices without compromising crop yields.

HIGHLIGHTS

- The incresing pressure to meet global creal production poses great challenge.
- A changing environment further threatyens crop production.
- INM contributes to mitigate the environmental costs are remarkable.
- High crop productivity and less environmental impact can be achieved under INM.

Keywords: Crop Ecology, Crop production and Integrated Nutrient Management (INM)

The preservation of fertility is the first duty of all that live by the land and there is only one rule of good husbandry – leave the land far better than you found it (George Henderson 1944).

Crop ecology is a branch of agricultural science that deals with the study of the relationships between crops and their environment. It facilitate the understanding of how crops interact with various factors such as climate, soil, pests, and management practices. Ecology is broadly known as

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the reciprocal relationship between organisms and their environment (surroundings). Life containing and life supporting environment is restricted to 5-20 Km thick layer around the globe is called as ecosphere or biosphere (earth where life exists). Biosphere comprises of two components the one called as parabiosphere having unhospital conditions i.e. polar region, highest altitude and deepest ocean etc. The another one is called as eubiosphere which is further divided into its segments as atmosphere (air), hydrosphere (water) and lithosphere (earth). Out of these atmosphere is of utmost importance for agriculture which is comprised of troposphere, stratosphere, mesosphere and thermosphere. The flow of energy between sun and air, water and soil produces elements of environment as soil, water, temperature, light, wind, fire and biotic factors. Plant growth and geographic distribution (where the plant can grow) are greatly affected by the environment. If any environmental factor is less than ideal, it limits a plant's growth and/or distribution. For example, only plants adapted to limited amounts of water can live in deserts. Either directly or indirectly, most plant problems are caused by environmental stress.

DISCUSSION

Why Ecology important in crop production

By ensuring proper nutrient management, crop ecology helps in maintaining soil fertility and preventing nutrient imbalances, leading to improved crop yields. Pest and Disease Management: - Crop ecology examines the interactions between crops and pests, diseases, and weeds.

Ecological Factors affecting Crop growth

In some cases, poor environmental conditions (e.g., too little water) damage a plant directly. In other cases, environmental stress weakens a plant and makes it more susceptible to disease or insect attack. Environmental factors that affect plant growth include light, temperature, water, humidity and nutrition.

Soil- Plant- water relationships

Plants are dependent upon soil for anchorage, water and nutrients and hence plant and soil are strongly influenced by each other and also because of the complexity and dynamic nature of soil. Soil characteristics are undergoing continual change, the rates of these changes being highly dependent upon several environmental factors. Soil is more critical as a factor of plant environment in natural habitats, for extreme conditions which are en- countered, are not tempered by corrective cultivation, irrigation, drainage and fertilizers etc. Importance of soil texture to plants varies as resistance to root penetration, infiltration rate, water movement, water holding capacity, fertility, structure, aeration, temperature. While soil organic matter plays important role in the plant environment as nutrient source, food for soil organisms, source of toxins, affecting water holding capacity, adsorptive capacity and mechanical effects. Soil organisms play role in nutrient cycles, toxins, stimulants, nitrogen fixation, soil mixing, soil aeration, aggregation, uptake of water and solutes. While soil moisture, air and solutes are also very important. Besides these parameters soil pil also has important role to play. Water is of paramount importance to the plants as universal solvent, medium, chemical reactivity of compounds, a raw material in photosynthesis maintenance of turgidity, existence of protoplasm, cooling by transpirations and changes in biochemical reactions. There are several forms of water i.e. humidity, cloud, fog and precipitation etc. Atmosphere vapour is important to plants as it affects intensity of solar radiation, evaporation and transpiration, source of soil moisture, direct use by plants, as soil moisture the precipitation losses to atmosphere soil temp., soil porosity, slope smoothness.

Temperature Aspect

There is relatively little biological activity below 0°C or above 50°C because of immobilization of water and heat destruction of vital proteins respectively. Spatial variations in temperature affects colour and composition of surface, porosity and water content of soil, plant cover, snow cover, latitudinal variation, vertical gradients in soil, atmosphere and water bodies etc. Temperature of plant organs tends to follow the immediate environment closely. This is true of root temperatures which are almost identical with soil temperatures while shoot temperatures may differ several degrees from air temperatures depending on the absorption of solar radiation which elevates tissue temperature. Besides it affects transpiration, physiological processes, thermoperiodism, phenology, cold injury and drought injury, incidence of insect pest and diseases etc.

Energy Aspect

Energy necessary to sustain life on earth is derived from sunlight directly by green plants or indirectly by other organisms must depend upon organic compounds synthesized by green plants. Chlorophyll though its ability to absorb radiant energy from sun and convert it into chemical energy contained in simple sugar molecules, is the link between all living organisms and solar energy Light also exerts many effects up on plants, e.g. on several phyiological processes and chemical composition of plants.

All radiant energy is received on earth from sun in the form of electromagnetic waves varying in length. Light varies in intensity and duration, spatial variations in light intensity are mainly due to temperature, water, suspended particles, vegetation, topography and latitude. While temporal variations in light are also of very much importance. Light affects number of plant functions depending upon the kind of plant, stage of life cycle and variations in other factors. Major plant processes affected by light are photosynthesis, transpiration, germination, reproduction and photoperiodism etc. by temperature and other factors. Besides these are also influenced.

Atmospheric gases Aspect

In terms of ecology atmosphere must include not only the gaseous fraction of planet but also the gas masses which penetrate or originate in the soil and plant tissues. The effects of atmosphere on plants are supply of CO, for photosynthesis and 0, for respiration besides indirect effects such as distribution of heat and light and promoting transpiration, pollination and dissemination. Soil aeration, respiration of soil organism and roots, pore space and size, morphology and physiology of plants is directly affected.

Wind influences plants in terms of CO, replenishment, cooling, desiccation, dwarfing, breakage and lodging, soil erosion etc.

Plant nutrition vs Fertilization

Plant nutrition often is confused with fertilization. *Plant nutrition* refers to a plant›s need for and use of basic chemical elements. *Fertilization* is the term used when these materials are added to the environment around a plant. A lot must happen before a chemical element in a fertilizer can be used by a plant.

Plants need 17 elements for normal growth. Three of them--carbon, hydrogen and oxygen--are found in air and water. The rest are found in the soil. Six soil elements are called *macronutrients* because they are used in relatively large amounts by plants. They are nitrogen, potassium, magnesium, calcium, phosphorus and sulfur.

Most of the nutrients a plant needs are dissolved in water and then absorbed by its roots. In fact, 98 percent are absorbed from the soil-water solution, and only about 2 percent are actually extracted from soil particles.

Fertilizers Aspect

Fertilizers are materials containing plant nutrients that are added to the environment around a plant. Generally, they are added to the water or soil, but some can be sprayed on leaves. This method is called *foliar fertilization*. It should be done carefully with a dilute solution, because a high fertilizer concentration can injure leaf cells. The nutrient, however, does need to pass through the thin layer of wax (cutin) on the leaf surface.

Fertilizers are not plant food! Plants produce their own food from water, carbon dioxide and solar energy through photosynthesis. This food (sugars and carbohydrates) is combined with plant nutrients to produce proteins, enzymes, vitamins and other elements essential to growth.

Green plant is commonly referred as an independent organism in contrast to other plants and animals that cannot synthesize their own food. CO_2 used by green plant in photosynthesis has been released in respiration by other organisms, and the oxygen used in respiration has been accumulated by previous generations of green plants. Amount of heat, light, moisture and nutrients, available to one plant are all conditioned by proximity of other plants and most of the soil nitrogen as organic nitrogen. Environment of any organism is always a part of biological as well as physical parameters. Lichens, mycorhizae, nitrogen-fixing bacteria and blue green algae in roots, stems and leaves and algae inhabiting protozoa etc. play very important role in the nutrient management by way of symbiotic N fixation, mycotrophy and allelopathy. Roots of most legumes produce gall-like nodules inhabited by bacteria which fix atmospheric N into organic compounds that benefit the legumes. Legumes in turn furnishes the bacteria with foods, nutrients and water.

Blue green algae are associated with the roots or other organs of many higher plants and in some of these relationships there is evidence that the algae can fix nitrogen.

In fertile soils the rootlets are not mycorhizal. On the other hand, in soils deficient in N, P, K or Ca the absorptive power of long roots are invaded by fungi that take over the absorptive functions.

Fire affects the germination and the environment of plant. Because of fire N and S volatilized and escape from the habitat but all other mineral nutrients converted to simple water soluble salts that are readily available. If these can be adsorbed by the soil colloids or taken up by a new plant cover before they leach away, soil fertility is raised in consequence of burning. Warmer soil speeds up mineralization of humus, only the upper few centimeters of which are oxidised by fire. Nitrification is also increased by the warming. Burning is beneficial when it removes thick accumulation of organic debris with high C/N ratios. Besides in acid soils release of/k and other bases bring pH to a level where of nutrients availability is improved (Daubenmire, 1974).

It is obvious that ecology is very complex considering the several elements of environment and their interactions with each other. Besides though man is a component of biotic factors but its role of much importance in changing rather fluctuating the effects of all these parameters.

Green plants have unique ability to capture solar energy and convert it into carbohydrates, oils, proteins, cellulose and other compounds. On earth all plants fix only 0.1 percent of the incoming solar energy and of this agricultural crops accounts for about five per cent of the total energy fixed. This small amount of the sun's energy runs the life support system of bio- sphere. Commercial agriculture to increase energy efficiency need additional energy expenditure in form of preparing land, cultivating crops, planting and harvesting crops, irrigation, manufacturing fertilizers and transporting and supplying these materials (Miller, 1976).

Today world is a rapidly changing place, and agricultural research must respond to the new challenges and opportunities. It must obviously continue to develop new technologies that increase. food production in favoured and in more hostile environments. But at the same time attention must be paid very closely to the ecological realities (CIMMYT 1995). Swaminathan (1968) cautioned that initiation of exploitive agriculture without a proper understanding of various consequences of everyone of the changes introduced in a traditional agriculture and without first building up a proper scientific and training base to sustain it may only lead us into an era of agricultural disaster in long run rather than to an era of agricultural prosperity. After a gap of nearly three decades, Swaminathan (1990) commented on the status of sustainable agriculture that it was clear from the beginning that the indiscriminate use of chemicals and non-adoption of ecologically sound crop management practices might have a number of unfavourable effects. Public health problems could arise and the sustainability of high yield could be threatened. Therefore, agriculture performance is assessed on the basis of productivity, stability, sustainability and equity. The equity must be considered at both level i.e. intragenerational means a fair deal to economic and ecological disadvantaged and secondly Intergenerational i.e. conserving ecological foundations of the sustainable advances in biological productivity. Similarly today performance of crop must be viewed through its adaptability, flexibility, reliability and mutability (as in case of maize).

Role of Fertilizers

There are two dimensions in considering fertilizers role in man's environment i.e. production and use. Production affects both air emissions (N and S oxides, Flourine etc.) and water quality. While the use of fertilizer affects the ground and stream water.

Plants obtain their nutrients from weathered product of soil parent material, from natural fixation processes or from commercial fertilizers.

Most soluble nutrients (nitrogen, carbon and sulphur) which also occur in the volatile state, are easily recycled. While others such as phosphorus and potassium, which lack a naturally in occurring gaseous phase must be continuously renewed since they do not have a complete cycle. These nutrients if not intercepted by plants or held by soil reached to the ocean. Natural losses from land through weathering, leaching, run-off and erosion have removed large amount of nutrients from soils. This process of cycling nutrients to the oceans is continuing today.

Most of the earth's nitrogen is not contained in the atmosphere or the biosphere but is present in the earth's rock and sediments. Nitrogen is taken up by plants in two forms i.e. NO (most common) adsorbed by soil, free to move with water, denitrified in waterlogged soils, lost to air as molecular gas and tied up by microorganisms. The another form is NH_3 which get adsorbed by soil, traces leaches from soil, nitrified, converted to NO_3 with high temperature, fixed in minerals, form ammonia gas and lost to air in alkaline soils and tied by microorganisms also.

Table 1: Generalized ranges of potential pathways for nutrient budget in soil

Sl. No.	Pathways	Magnitude range (%)	
		N	P
1	Crop uptake	40-70	10-20
2	Gaseous losses (Denitri.)	5-35	—
3	Erosion	0-20	0-20
4	Immobilization	10-40	50-90
5	Leaching	0-20	0-50

Miller, 1976.

Erosion, run-off, leaching and denitrification are the major ways of nitrogen loss. In absence of O_2 in waterlogged soils NO_3 changes to N_2 and volatilization takes place in alkaline soils. Although denitrification is significant pathway for N loss but environmental quality is little affected because there is loss as N_2 which is already 79% in it. Volatilization losses are not of much significance. As regards to environmental quality erosion and solution forms of losses are of major importance. Phosphorus reacts with Fe, Al, clay, organic matter and CO_3 but does not get lost as gas. Generalized ranges of potential pathways for nutrients budget in soil given in Table 1 (Miller, 1976). The quantity varies with location, management and time. Therefore, major pollution is caused by nitrogenous fertilizers as below:

Fertilizer N in soil → Food (proteins)
↓
Leaching as NO_3 → Denitrification → N_2 and N_2O
↓ ↓
Ground water Decomposes Ozone in stratosphere.

The major sources of fixed nitrogen release in to the environment are given in Table 2 (Miller, 1976). It is emphasized that fertilizer accounts for 13 percent of total N released and yet, part of fertilizer N component is contained in other sources such as livestock and human waste. Therefore agriculture is one of the sources and nutrient addition often do leak to the ecosystem. Today the total world consumption of fertilizer N, P and Kis 78, 16 and 22 m. tons/annum respectively (F.G.W., 1991). The demand for fertilizers in the future is expected to expand with world population growth and the need for food (F.G.W., 1991, Jenkinson, 1990). While the global problem is clearly stated by the club of Rome and confirmed by recent evaluations (Meadows *et al.* 1992) that resources decline and the environmental pollution increases in an exponential way.

Table 2: Major sources of fixed nitrogen released in to the environment in U.S.

Sl. No.	Sources	Percent
1	Soil organic matter	37.0
2	Livestock manure	18.5
3	Fixed by soil organisms	18.5
4	Fertilizers	13.0
5	Precipitation	9.0
6	Human waste	4.0

Miller, 1976.

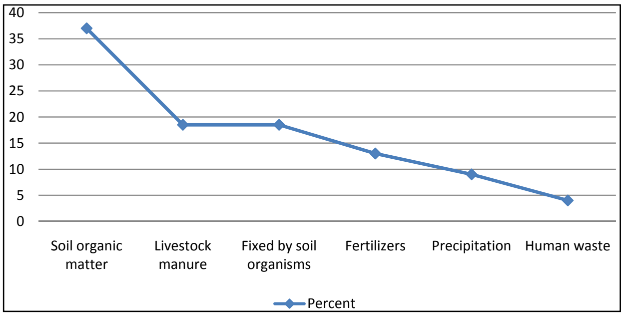

Fig. 1: Major sources of fixed nitrogen released in to the environment in U.S.

In many European countries use of animal slurry and grazing are common practices which resulted in very high agricultural NH_3 emission density reported by Isermann (1987) Fig. 2. The indiscriminate use of nitrogen has resulted its way to the food and the body of human beings as reported by Isermann (1990) Table 3.

UNCED Conference held at Rio de Janerio in 1992 initiated concern that paddy fields in Asia are a source of Green house gas emission of methane and Nitrous oxide which contributed towards global warming and depletion of Ozone layer. Nitrification inhibitors reduce gas emissions after urea is applied to rice growing soil The most effective chemical is wax-coated calcium carbide which slowly releases the inhibitor Acetylene, results reduction in fertilizer pollution of environment including atmosphere.

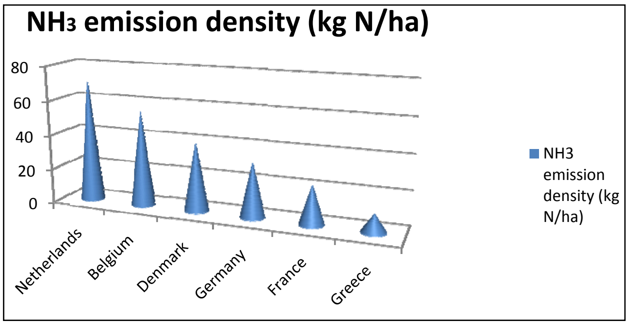

Fig. 2: Agricultural NH_3 emission density of various countries (Kg N/ha) Isermann (1987)

Table 3: Way of nitrogen from crop production to human consumption (N kg/ha/yr)

Sl. No.	Way of Nitrogen –crop prod.to human consumtion	N kg/ha/ year
1	Total agricultural input (Fertilizer, Feed conc. Sewage, Biol. N fixation)	218
2	Nitrogen in seeds, grains, vegetables	23
	Meat, Milk, Egg	28
3	Nitrogen in produces bought by man	28
4	Nitrogen in food actually eaten	22
5	Nitrogen remaining in human body	0.07

Isermann (1990).

Chinese scientists have developed a new and promising inhibitor based on natural chemical from microorganisms isolated from paddy soil (Crasswell, 1992).

Besides the improper and indiscriminate use of fertilizers there is also improportional use of energy sources in agriculture as reported by Subudhi (1991) Table 4 which also needs attention.

Table 4: Annual energy use in agriculture sector

1.	Chemical fertilizer	69.2 %
2.	Human	15.3%
3.	Animal	9.1%
4.	Pesticide	2.9%
5.	Organic manures	2.3%
6.	Electricity	1.2%

Subudhi (1991).

Mengel (1993) while summerizing his findings mentioned that crop production has a positive balance which even can be improved by an adequate fertilizer application. World phosphate reserves are limited and therefore fertilizer phosphate should be used with high efficiency. In intensive animal farms phosphate rates may exceed by far the demand of the crop and therefore result in a heavy waste of phosphate. The same applies with application of nitrogen in form of slurries. Nitrate may be leached out from agricultural land and pollute surface and ground water and the denitrification product N_2O is involved in decomposition of Ozone in stratosphere. Also in future crop production needs fertilizers of which the application should be handled carefully in order to reduce pollution of the environment as much as possible. Hence excessive slurry or intensive animal forms of phosphate result in a heavy waste of phosphate. While global phosphate reserves will last about 500 years if consumed at todays rate.

Management of N fertilization

Management of N fertilizing can be optimised in different ways (Amberger, 1993).

A clear calculation of required amount of N for the expected yields is necessary on an input-output basis. N-losses and agro-techniques to avoid them:

- NH_4 volatilization by immediate incorporation of the inorganic or organic fertilizers into the soil.
- Denitrification by optimising soil structure.
- NO_3 leaching by straw manuring, late application of slurry and late incorporation of green manure.

Nitrification inhibitors (e.g. dicyandiamide, DCD):

- When added to NH_4 or Urea fertilizers, they show economic advantage and preserve fertilizer N from being translocated out of the root zone or leached out.

- As an additive to organic waste materials from plant and animal production or industrial processings they inhibit nitrification. Efficient N management in cropping systems is a necessary demand both for economic and ecological reasons.

According to Shaviv (1993) environmental pollution and damage is two dimensional:

1. Accumulation of pollutants i.e. Nitrates, Nitrites, Nitrozoamines in plant, water, soil or toxic gas ammonia or Nitrons Oxides which affect ecosystem and life exposure to ultraviolet radiation.
2. Soil degradation and damage i.e. salt concentration, high pH, displacement of Ca, Mg, hydraulic properties, accele- rated algal growth (due to N & P) and low infiltration.

He suggested few measures to control above problems that:

1. Synchronise N and other nutrient supply with plant need.
2. Provide optimal condition for plant growth and development.
3. Maintain optimal composition of nutrients.

Hence, an environmentally sound practice must lead to:

1. Increase in yields due to maintenance of optimal $NH4/NO_3/K$ proportions in soil.
2. Increase bio-availability of P due to synergistic effects between P and K or N forms.
3. Increase micro-nutrients availability due to synergistic interaction in rhizosphere.
4. Control the soil damage (compaction, erosion and weathering).
5. Reduce environmental pollution induced by accumulation of toxic materials in water, plant or in the atmosphere.
6. Improve conservation of natural resources due to reduced losses of nutrients.

Besides these in tropical and subtropical environments the oxidation of humus is high and soil generally tends to be lower in organic matter content. In such soils incorporation of residues is needed.

Likewise in eroded soils where nutrient status tends to be quite low due to continuous cultivation for centuries. In such soils cereal-legume crop sequences or their mixtures need to be followed.

Under intensive cropping systems weeds, insects and pathogens multiply and spread for such situations varieties with genetic resistance are needed.

Therefore, there is need to produce food with a high quality and quantity but it must be accomplished with a minimum impact on environment.

Since agriculture is bound to operate in an open system, the fate of fertilizer in environment is a many faceted problem because the production, use, uptake and loss varies according to the ecosystem in which cropping system operates.

CONCLUSION

The world vision of no hunger, food security and zero poverty followed by enhancing the living standard of rural people, agricultural transformation is the biggest challenges of the time. Due to alarming population brust and cultivable land scarcity, the change in agronomic practices that could bring a significant impact on crop production in relation to crop ecology is urgently needed. The concept of using different sources of plant nutrients combined to check nutrient deplition, maintaing soil health and crop productivity in relation to crop ecology is the key role of INM.

Fertilizers must be used in growing crops as per the crop demand, soil fertility status, use of inhibitors, blended with residues and inclusion of legumes in cropping system so that it should not result serious environmental hazards. However, excessive, indiscriminate and irrational use of fertilizer where land is left bare for sometime in a year with excessive irrigation water will result environmental pollution due to erosion, leaching and volatilization etc. It's important to understand how these factors affect plant growth and development. With a basic understanding of these factors, you may be able to manipulate plants to meet your needs, whether for increased leaf, flower or fruit production. By recognizing the roles of these factors, you'll also be better able to diagnose plant problems caused by environmental stress.

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