

Nutrient Management in Rainfed—Dry Land Agro-Eco Systems in the Impending Climate Change Scenario

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Introduction

In order to feed the burgeoning population there is urgent need to double the cereal crop production by the year 2050 and also to meet the United Nations Millennium Development Goals of reducing the number of hungry people to half by 2015, there is utmost need to breed potentially high yielding varieties to match up the requirement along with corrective measure to bridge the huge gap between attainable yield (yield obtained in demonstration trials) and the average yield harvested by farmers. The Rainfed—Dry Land Agro-Eco Systems (RDL-AES) has vast untapped potential to feed a major portion of population, currently sharing about 44 per cent of total foodgrain production with bulk of (around 90 per cent) coarse cereals, pulses and oilseeds of the nation. Under global warming and climate change scenario the nutrient management in this fragile ecosystem of crop production could play vital and bigger role than ever as the response history of many of nutrient may not be as useful as they were in previous occasions obviously due to evolution in all the inputs and marked change in climate. It is estimated that organic and biofertilizer may help to bridge this gap by supplying 6-million tones of plant nutrients, where as soils and efficient use of plant nutrients may contribute to the extent of three million tones. The INMS helps to restore and sustain soil fertility and crop productivity. It may also help to check the emerging deficiencies of nutrients other than nitrogen, phosphorus and potassium. Further, it brings economy and efficiency in fertilizers. The INMS favorably affects the physical, chemical and biological environments of the soils.

The first green revolution by-passed grossly dry land farming areas, due to endless reasons but lack of assured water supplying mechanisms is one of the prominent reason behind its low input responsiveness than the other once. Despite all possible and sincere efforts the net irrigated area in India increased from about 21 million ha in 1950-51 to 58 million ha only by 2008-09. This is the reason for poor increase in the cropping intensity, from 111 to 137 per cent achieved in the same period. Due to climate change in all agro-ecosystem in general and in rainfed dry land farming in particular which is more fragile and vulnerable than others, the loss in productive potential of soils is attributed to an imbalanced use of fertilizers and chemicals, overmining and poor replenishment of nutrients, loss of

organic carbon, pollution, lack of biological activity, etc. Therefore, there is need of concerted efforts to grasp the impact of climate change on agricultural production in this region in a more equitable, efficient and rational systems and institutions for the utilization of scarce resources. Now, India needs new technologies and new production regimes for rainfed and dry land agriculture. Based on an estimate of National Commission on Agriculture, even after realizing the complete irrigation potential of 113 m ha, nearly 50 per cent of cultivated area of our country will continue to be rainfed.

Because of an uneven and erratic rainfall, these soils are characterized by low moisture status, so, majority of mineral nutrients are immobilized and remain fixed in soil, thereby causing low availability to plants. From a long experience of experimentation conducted under All India Co-ordinated Research Projects of Dryland Agriculture, it has been recognized that "dried soils are as hungry as they are thirsty".

Diversity in the natural resources in the country ranges from shifting cultivation to high intensity cropping systems. In rainfed dry land agro-eco system, there are five types of cropping systems prevailed which are entirely distinct to each other by one or another way. These are rainfed coarse cereal based cropping systems, pulse based cropping systems, oilseed based cropping systems, cotton based cropping systems and rice based cropping systems. The major crops of the rainfed dry land agriculture are listed in table 1.

TABLE 1—IMPORTANCE AND ROLE OF RAINFED DRY LAND AGRICULTURE IN INDIAN FOOD SECURITY SYSTEM.

Particular	Magnitude
Total Geographical Area in India (M ha)	329
Land area under agriculture in India (M ha)	142
Rainfed dry land (%) of total cultivated area	66
Human population (%) of India in rainfed dry land	40
Livestock population (%) of India in rainfed dry land	67
Coarse cereals (%) of India in rainfed dry land	91

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TABLE 1—IMPORTANCE AND ROLE OF RAINFED DRY LAND AGRICULTURE IN INDIAN FOOD SECURITY SYSTEM—*Contd.*

Particular	Magnitude
Pulses (%) of India in rainfed dry land	90
Oil seeds (%) of India in rainfed dry land	85
Cotton (%) of India in rainfed dry land	65
Rice (%) of India in rainfed dry land	55
Foodgrain production of India (%)	44

To obtain the maximum production potential of a particular crop depends on the environment and the skill of the farmers in identifying and eliminating those factors that reduce the production potential. The essential nutrients required by higher plants are exclusively of inorganic nature. According to the criteria proposed by Arnon and Stout as early as in early nineteenth century, at least 16 chemical elements are known to be essential for every higher plant. Major portion is covered by Carbon (C), Hydrogen (H) and Oxygen (O) which is managed by air and water. Others like N, P, K, S, Ca, etc. are needed in less amount and need to supplement, as soil is not able to supply them in adequate amount. N and P deficiencies are almost universal in all dryland soils. In coarse textured soils, potassium deficiency are also common, secondary and micronutrient like S and Zn, outside application has also been reported to fulfill the crop requirement and to maintain the fertility status of soil. But low moisture status of soil limited the scope for extensive use of chemical fertilizers in this area. On the other hand, addition of organic matter improves the hydrophysical properties of soil by conserving more and more water along with the supply of almost all the essential nutrients to crop plants. However, due to paucity of organic sources to meet total nutrient requirements their conjunctive use with inorganic fertilizers is desirable. Therefore for sustainable crop production in dryland areas integrated nutrient management is a best approach. Integrated nutrient management system (INMS) involves the use of chemical fertilizers in conjunction with organic manure's / wastes coupled with inputs through biological processes. The results of a large number of experiments on manure's and fertilizers conducted in the country reveals that neither the chemical fertilizer alone nor the organic sources exclusively can achieve the production sustainability of soil as well as crops under a highly intensive cropping system. To maintain optimum yield, to monitor and improve the soil fertility status and to provide crop nutrition package on long term basis, which are technically sound, economically viable, practically feasible and environmentally safe. The INMS has proved superior to the use of its each component separately, besides the interactive advantages of combining organic and inorganic sources of nutrients. The present level of

fertilizer production in India is not enough to meet the total plant nutrient requirement. The gap between demand and supply of fertilizer is expected to widened further and it may reach upto 15-20 million tones by 2020 AD.

Component of INMS :

INMS consists of use of inorganic fertilizers, cropping systems, legumes as a green manure; as inter crop, organic manures, crop residue management and incorporation of factory wastes, recently developed bio-fertilizers etc. Each component is discussed briefly as under.

Inorganic Fertilizer:

In modern agriculture chemical fertilizer is chief source of nutrient supply for getting better response. Use of proper kind and form of high analysis chemical fertilizers and their appropriate time and mode of nutrient application for feeding the crop to take optimum production, different kind of fertilizer in market are available which is mentioned below.

(A) Nitrogen Nutrition :

Amongst plant nutrients essential for growth, nitrogen is of prime importance in crop production, though constitutes only a fraction of one per cent of the total dry weight. Nitrogen is transported from roots to the leaves where the process of assimilation takes place and it is transformed in to protein a substance which constitutes an important part of protoplasm. Growth is usually rapid with abundance of carbohydrate and nitrogenous compounds. Nitrogen liberates from soil environment which make its practically very difficult to utilized by plants for its requirement, the reason could be de-nitrification, volatilization of ammonia, leaching of nitrates, fixation of ammonia or some times biological immobilization by bacterial activities. Factors responsible for the above losses may be faulty management of irrigation water, improper time, mode and amount of N application, improper selection of form and kind of N fertilizers, poor and faulty weed management practices, soil type and its pH and agro-climatic conditions of the particular region. For obtaining good fertilizer use efficiency choice of correct kind and form of fertilizer is necessary. In case of sugarcane urea and ammonium sulphate is most effective chemical fertilizer.

(B) Time and Mode of Nitrogen Application :

Nitrogen is one of the most important limiting nutrients for crop production, so several workers studied the effect of nitrogen nutrient on the growth yield and quality parameters. There is general trend that due to increasing rate of N fertilizer growth and yield is increases up to some extent. Nutrient absorbed by plant during tillering phase dose not exceed 25-30 per cent of its total nutrient absorbed up to the maturity stage. Initial high concentration of nitrogen in crop is necessary because during this stage tillers are coming out. To check the

denitrification losses from sugarcane field number of agricultural chemicals including nematicides, pesticides and fungicides like *N-serve*, *Nitropryrine*, *A.M*, *Thiourea*, *Potassium azide* etc. are useful and available in the market. It was observed from several locations of India that the N application was ranged to sugarcane from 60 to 400 kg N/ha and yield can ranged from 21.5 to 305 t/ha while the yield response for cane per kg N applied was highest in 60 kg N (4.5q) and lowest in highest N dose 1.8q cane per kg applied N.

Phosphorus Nutrition :

Phosphorus is one of the essential nutrient and also known as 'key elements' for plant life. It maintains the adverse effect of high application of nitrogen fertilizers. Several workers reported that application of phosphorus fertilizer has positive effect on crop in dryland situations. Crops of dryland were not responding earlier to P application in most of the soils. With increasing deficiency of P in Indian soils in recent years sugarcane has responded to P application. P is generally applied as Basal and mostly water soluble form of phosphorus are applied i.e. Single Super Phosphate (SSP), Di Ammonium Phosphate (DAP) etc.

Potash Nutrition :

This nutrient require larger amount than nitrogen because of its role in photosynthesis, translocation of sugar, protein synthesis etc., so its requirement is made through overall growth period, and due to this reason initial basal application is better and generally, potassium sulphate (K_2SO_4), muriate of potash (KCl) are used as source of potassium.

Sulphur :

The responses of crop in dry land rain fed agriculture are no more limited to only NPK. Sulphur is given through Ammonium Sulphate (23.7%), and Pyrites (53.5%) etc. Generally the requirement is more in graminaceous plant as compare to leguminous because it play vital role in oxido-reduction process of respiration, because of being a part of ferredoxin. Sulphur (S) is involved in amino acid and protein synthesis, enzymatic and metabolic activities in plants. Its deficiency is rapidly emerging in areas under oilseeds and pulses due to higher removal of S by crops. Fertilizers required for correcting the deficiency of all these nutrients especially sulphur for oilseeds and pulses, reduction in yield often blamed to sulphur deficiency.

Micro Nutrients :

Plant takes zinc in the form of Zn^{2+} . Zinc is required in a large number of enzymes and plays an essential role in DNA transcription. There is a need to ascertain and promote the use of various types of fertilizers required to correct the deficiency of all these nutrients especially zinc for cereal crops. Deficiency symptoms of Zn in cereal crops are more

pronounced, hence some time reduction in yield often correlated to low availability of zinc only. It is applied through soil but foliar feeding can also be done. Most important source is $ZnSO_4 \cdot H_2O$ (35% Zn). Zinc is applied in soil at the rate of 25 or 50 kg/ha. Two or four field trials with autumn planted cane showed a significant response to Zn in both cane and sugar yields. Other micronutrients like Fe; Mn is also responded to various degrees in this region to different crops. They are also applied through soil as basal but foliar application can also be done. The chief source is $FeSO_4$ and $MnSO_4$ for Fe and Mn respectively.

2. Cropping System Approach :

The INMS favorably-affects the physical, chemical and biological environments of soils. Some of the important sugarcane based cropping systems prevalent in the country is listed in Table 1. Being at least of 3-4 years duration, Sugarcane based cropping systems; is complex in its nutrient use pattern. Some crops have a considerable bearing on the additional nutrient requirement for itself. Need for nitrogenous fertilizer is about 50 % higher in long duration crop but the requirement for phosphorus is comparatively low because of the availability of residual phosphorus. A system approach of nutrient management for sugarcane cropping as a whole is therefore, considered much efficient. The quantification of fertilizer economy is possible only when the fertilizer needs and residual carryover of the full cropping cycle as against the individual crop are known. Limited studies on INMS rainfed dryland based cropping systems have been conducted. The optimum dose of nitrogen were worked out for sugarcane are 152, 175, 186, 231 Kg/ha, when grown in association with potato, coriander, mustard and wheat, fertilized with 120, 150, 60 and 100 kg N/ha respectively. INMS helps to restore and sustain soil fertility and crop productivity. It may also help, to check the emerging deficiencies of nutrients other than N, P and K. Further it brings economy and efficiency in fertilizers. The INMS favorably affects the physical, chemical and biological environments of soils.

3. Legume Bio-Mulching and INM :

In general the removal of plant nutrient is more in cereal crops than the legume crops therefore; legume is preferred to be included in crop sequence to sustain soil productivity. The legume in sugarcane farming system is grown as :

(A) Legume As Green Manuring Crops :

Before the chemical fertilizers come in use in dryland rainfed farming systems, green manuring was considered as an indispensable practice. As a result of that there was general recommendation to north India, to apply 1/2 to 2/3 nutrients through green manuring or organic manure. The principal green manuring crops included sunhemp, dhaincha, bean, guar, senji, berseem, methi, pea, khesari and lentil. The green manuring of legume crops give benefit of 19-43 per cent increase in the yield of almost all crops in the region.

B) Legume As Inters Crops :

Because of population pressure on land and availability of chemical fertilizers at cheaper rates, green manuring prior to main crop is considered as waste full practice, hence it is not preferred to miss a kharif crop for green manuring, so, legumes in inter row spaces as intercrop is taken. Legumes suitable for intercropping are gram, lentil, pea and khesari for spring planted crops, and summer legume like moong, urd, and cowpea are popular intercrops.

Organic Manure :

The organic manures play a direct role in supplying macro and micronutrients and an indirect one by improving the physical chemical and biological properties of soil. Farm yard manure, compost and oil cake from groundnut, castor, mustard, mahua, safflower etc. are very commonly used in dryland rainfed for increasing yield and improving soil fertility. These organic manures are bulky, slow in response and less effective than chemical fertilizers. A comparison of efficiency of manures would indicate that N- contained in bulky organic manures are nearly 40-50 percent as effective as that in chemical fertilizers. The observation may lead to conclusion that organic manures are inferior to chemical fertilizers, therefore, to derive the full benefits of organic manures, an integrated use with chemical fertilizer has been emphasized and advocate.

5. Crop Residues in INMS:

The crop residues like green foliage of crops, cane trash, rice and wheat straw etc. have been recycled in sugarcane cultivation. As a result economy in fertilizer N has been affected. The addition of green leaves from outside has some effect as above ground portion of green manure incorporated in soil. Glyricida, Karanj (*Pongamia glabra*) and Arak (*Caletropis gigantea*) are very popular in south India for green leaf manuring. Potato foliage containing; 2.6-2.7 percent N contributes 31 kg N/ha when used as green manure. Trash is the residue of sugarcane and on an average one hectare sugarcane field provide 8-10 t/ha trash. Incorporation of trash with fertilizer N increases the cane yield. It may also increase the cane yield by 30 per cent over control when 5.0 t/ha trash is incorporated with 75 kg N/ha and economy of 75 kg N/ha has become obtained in south India.

6. Factory Wastes in INMS :

The by-Products of factories like waste from distillery, molasses and press mud cake etc. from sugar industry have been reported to increase the yield of cane. The production of press mud cake (PMC) is about 3 to 7 percent of the amount of cane crushed in sugar factories. Press mud is of two type i.e. sulphitation press mud and carbonation press mud cake. The press mud, which is made by sulphitation process, i.e. sulphitation press mud is good source of nutrient and amendment for saline-alkaline soil. The press

mud which is made by carbonation process of sugar making i.e. carbonation press mud is useful source of nutrient supply and Amendment for acidic soil. Press mud cake has great potential to supply nutrient in addition to favorable effect on physical chemical and biological properties of soil during last three decades. PMCs have assumed greater importance in cane cultivation. PMCs have been found beneficial in increasing the yield of sugarcane. An economy of 50-70 kg N/ha has been obtained by several workers in sugarcane ratoon cropping system by integrated use of PMCs and fertilizer N. PMCs have also increased nitrogen use efficiency by 4-8 per cent. Sulphitation press mud cake (SPMC) found to be increasing organic carbon and availability of NPK and micronutrient in soil.

7. Bio-Fertilizer in INMS :

The Nitrogen balance studies using ^{15}N have provided direct evidences for N fixation taking place in several crops including non-leguminous crops. Some of the species of *Azotobacter*, *Azospirillum* and *Bacillus* have been reported to economics of fertilizer N in sugarcane and other crops to the extent of 50 percent on farm trials conducted in Tamil Nadu have indicated reduction in N dose by about 25 percent with the application of both *Azospirillum* and *Azotobacter*.

Studies on the efficacy of bio-fertilizers in reducing the N dose in sugarcane under subtropical conditions have revealed that there is no significant difference in the cane yield levels obtained with 75 percent N with soaking sets in *Azospirillum* and 150 kg N/ha. It is observed that different isolation of *Azotobacter* has different capacity for N fixation. In Bihar an economy of 30-35 kg N/ha is obtained with *Azotobacter* application. New microorganism like *Accetobacter diazotrophicus* are found to be associated in large number in roots and stem of non leguminous and *Herbaspirillum seropedicae* is reported to associate on all parts of sugarcane viz., roots stem and leaves of non leguminous.

Conclusion :

Along with other factor influencing the performance of crop in dryland rainfed agriculture, balance nutrition is one major aspect, which can be successfully done by conjunctive use of all the available resources in a sustainable manner. INMS advocates the uses of high analysis chemical fertilizers, inclusion of legume and other crops in cropping systems. In this system legume is also utilized as a green manure and as inter crop. Organic manure and crop residue are excellent source of various major and micro nutrients, incorporation of factory waste, and recently developed biofertilizer. INMS fine tuned with nature i.e. ecology of region / locality, which will decently having longevity over any single source, be it chemical or organic and ultimately prove to be more efficient to mitigate imminent climate with excellent productivity.

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