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Customized fertilizer formulation

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Abstract

According to FCO, customized fertilizers are multi-nutrient carriers designed to contain macro, secondary and/or micro-nutrient both from inorganic sources and/or organic sources, manufactured through a systematic process of granulation, satisfying the crop's nutritional needs, specific to its site, soil and stage validated by a scientific crop model, capability developed by an accredited fertilizer manufacturing. In short, customized fertilizers are multi-nutrient carriers facilitating the application of the complete range of plant nutrients in right proportion to suit the specific requirements of a crop during its stages of growth. They are unique and ready to use granulated fertilizers, formulated on sound scientific plant nutrition principles integrated with soil information, extensive laboratory studies and evaluated through field research. (Rakshit *et al.*, 2012). CF's can maximize nutrient use efficiency and are ultimately programmed to improve soil fertility. Hence, they fall under the category of environmental friendly fertilizers (Rao and Rahman, 2011). /marketing company. In short, customized fertilizers are multi-nutrient carriers facilitating the application of the complete range of plant nutrients in right proportion to suit the specific requirements of a crop during its stages of growth. They are unique and ready to use granulated fertilizers, formulated on sound scientific plant nutrition principles integrated with soil information, extensive laboratory studies and evaluated through field research. (Rakshit *et al.*, 2012). CF's can maximize nutrient use efficiency and are ultimately programmed to improve soil fertility. Hence, they fall under the category of environmental friendly fertilizers (Rao and Rahman, 2011). Customized fertilizer is to promote site specific nutrient management with a view to achieve the maximum fertilizer use efficiency of applied nutrient in a cost effective manner. The customized fertilizer may include the combination of nutrients based on soil testing and requirement of crop and the formulation may be of primary, secondary and micro-nutrients. It is the time to provide incentives to farmers using 100% water soluble fertilizers in view of quality of produce, ready to use form in a balanced way to maintain soil health. At last, the conclusion is, the farmers using customized fertilizers would not have to buy different fertilizers, or worry about the quantity of fertilizers to be added.

Keywords: customized fertilizer, nutrients site specific management

Introduction

Fertilizer is one of the key inputs in augmenting food grain production. Fertilizers alone contribute towards 55 per cent of additional food grain production (Kaleeswari, 2013) [3]. Food grain demand of India is about 300mt per annum by 2020. Since there is no likely prospect of any further increase in the area under cultivation over the present 142 mha, much of the desired increase in food grain production has to be attained by enhancing the productivity per unit area. The efficiency of fertilizer nitrogen is only 30-40% in rice and 50- 60% in other cereals, while the efficiency of fertilizer phosphorus is 15-20% in most crops. The efficiency of K is 60-80%, while that for S is 8-12%. As regards the micronutrients, the efficiency of most of them is below 5% (Rakshit, 2002) [9]. Intensive agriculture, involving nutrient-exhaustive crop varieties and continuous neglect of nutrient replenishment lead to the depletion of soil fertility and decline in crop productivity. Extensive mining of nutrients and imbalanced use of chemical fertilizers depleted secondary and micronutrients in soil and are considered as the main reasons for low response of crops. This calls for 'site-specific nutrient management' (SSNM) and development of customized and value-added fertilizers, especially micronutrient fortified fertilizers (Prasad, 2012).

Multi nutrient deficiencies are becoming common in soils and as a result the partial factor productivity is continuously decreasing. All these are due to the decreased use of organic manure and imbalanced use of chemical fertilizers, which ultimately lead to low fertilizer use efficiency.

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Considering the fact that about 40-50% of the applied fertilizer nitrogen is lost by ammonia volatilization, leaching, run-off and denitrification, development of more efficient nitrogen fertilizers such as neem-coated urea needs to be encouraged by providing price incentive to the fertilizer manufacturers. But most of the present suite of fertilizer products was developed more than 40 years ago. Over the past 25 years, no "new" efficient fertilizer product has been developed – particularly no product affordable for use on food crops by farmers in less developed countries. New and improved fertilizers are critical to help feed the world's growing population, provide sustainable global food security and protect the environment. Major recommendations emanating from the above discussion is that there is a dearth need of developing new and improved fertilizers i.e., customized fertilizers based on soil-test-crop response studies for major cropping and farming systems in different agro-eco regions of the country.

Customized fertilizers

According to FCO, customized fertilizers are multi-nutrient carriers designed to contain macro, secondary and/or micro-nutrient both from inorganic sources and/or organic sources, manufactured through a systematic process of granulation, satisfying the crop's nutritional needs, specific to its site, soil and stage validated by a scientific crop model, capability developed by an accredited fertilizer manufacturing /marketing company.

In short customized fertilizers are multi-nutrient carriers facilitating the application of the complete range of plant nutrients in right proportion to suit the specific requirements of a crop during its stages of growth. They are unique and ready to use granulated fertilizers, formulated on sound scientific plant nutrition principles integrated with soil information, extensive laboratory studies and evaluated through field research. (Rakshit *et al.*, 2012) ^[10]. CF's can maximize nutrient use efficiency and are ultimately programmed to improve soil fertility. Hence, they fall under the category of environmental friendly fertilizers (Rao and Rahman, 2011) ^[12].

Advantages of customized fertilizers

First and foremost objective is to promote site specific nutrient management. Usually farmers used to apply fertilizers without knowing any requirement of the crop. But here maximum fertilizer use efficiency can be achieved in a cost effective manner. Customized fertilizers are depends on soil, crop, water and specific nutrients. Nutrient management is a major component of a soil and crop management systems. Site specific nutrient management is applying those concepts to areas within a field that are known to require different management options from the field average. While most often thought of a relation to use of computer and satellite technology, the site-specific nutrient management does not require special equipment, and does not require a large farming operation. The technology tools certainly expand the capabilities for using site-specific management. Site-specific crop and soil management is really a 'repackaging' of management concepts that have been developed and promoted for many years. It is basically a systematic approach to apply sound agronomic management to small areas of a field that can be identified as needing special treatment. The components of site-specific management to small areas may not be new, but now we have the capability with new technology to use them more effectively (Tiwari, 2010) ^[19].

CF includes the combination of nutrients through various sources based on soil test information and requirement of the crop and it can provide desired quantity of major nutrients blended with micronutrients depending up on nature of crop/cropping system, nutrient requirements and yield targets fixed.

CF includes 100 percent water soluble grades as customized combination products required in various stages of crop growth based on research findings and it is readily available to crops and as it is a soil-crop-climate based fertilizer and is less influenced by soil, plant and climatic condition that lead to more uptakes of nutrients and less loss of nutrient. It supplies the plant available nutrients in adequate amount and in proper proportion, leads to the balanced application as it supplies not only primary nutrients but also secondary and micro nutrients and the particular texture ensures uniform distribution of nutrients. As it is 100 percent water soluble it can be used for fertigation purposes. So it has got importance in high-tech farming system. It can maximise nutrient use efficiency. Customized fertilizer satisfies crop's nutritional demand, specific to area, soil, and growth stage of plant. As the micronutrients are also added with the granulated NPK fertilizer the plants can absorb the micronutrient along with macronutrient which prevents nutrient deficiency in plant. Mixed fertilizers with micronutrients provide recommended micronutrient rates for the agricultural field at the usual fertilizer application. The farmer need not buy micronutrient separately at extra cost, thus reducing the total cost and helps the farmer to get better B: C ratio. It is found that incorporation of micronutrient with granular fertilizer at the time of manufacturing results in uniform distribution of micronutrient throughout granular NPK fertilizer and helps in more uniform distribution of nutrient with conventional application equipment. It is a very unique method developed in agriculture industry and has tremendous scope for future. It programmed to improve soil fertility hence are environmental friendly and improve soil health.

How to arrive at customized fertilizers?

Scientific principles were used as an ultimate guiding factor in deciding the grades of customized fertilizers. Following procedures were used to arrive at crop-soil specific customized fertilizer grades (CFG).

- Geo-referencing of chosen area
- Selecting sampling points on appropriate statistical procedure
- Actual sampling of the sites
- Analyzing sampling of the sites
- Analyzing soil, plant and water samples for nutrients and some soil characteristics
- Defining management zones
- Yield targeting in major management zones
- Computing crop removal of nutrients
- Calculating nutrient requirement (amount and ratio)
- Blending of nutrients based on the generated information

Primary components of customized fertilizers

In order to reach a particular formulation of CF, firstly go for defining the fertility management zones. Here soil analysis should be done to know the nutrient content. The geo-referenced sampling of soil, crop and water samples is done by a qualified team of crop specialist. Crop specialist use hand held GPS (Global Positioning System) and record latitude, longitude and altitude value of the field from where they take sample. Soil, crop and water samples are analysed

for nutrients to build database for deciding the management zones. Then based on the soil fertility rating and the nutrient requirement of the crop, actual nutrient requirement of that particular crop to that particular soil can be analysed. We can also analyse the actual requirement of that crop through various empirical models like QUEFTS/STCR, helps in the optimization of N, P and K for the same target yield of the crop.

Area and crop specific fertilizers have the advantages of balanced application and efficient response. Here all the nutrients according to the requirement of crop to that area are fusion blended and applied as customized fertilizers resulting in maximising the fertilizer use efficiency.

Approaches for Development of Customized Fertilizers

India has diverse and numerous agro-ecological zones and production environment. Most of the farmers are in small and marginal category with variable investment capacity. This grossly influence input usage and increase variability in soil condition. Therefore defining the scale of a region for developing customized fertilizer is a point of debate. Isolated successful stories of SSNM research may not be adoptable due to its limitation in operational application.

Preparedness of farmers and trade

As we see the customized fertilizers are knowledge driven. We have to prepare farmers for adoption of new nutrient package and its application technology. This is only way to assure the country 'Ever Green Revolution, Food and Nutritional Security'. Some of the general approaches to promote concept of customized fertilizers are listed below:

- Sensitization of the concept of customized fertilizer
- Large scale trials through ICAR and agricultural farms
- Farmers and dealers training
- Development of soil health and INM services
- Development of fertilizer metering and placement devices
- Demonstration at farmer's fields

Development of protocol

The research on customized fertilizers aims at developing and perfecting the scientific protocol to arrive at a crop and region specific grade. Conventional approach adopted by soil scientist/ agronomist might not be appropriate in handling multi-nutrient deficiency and inter-nutrients interaction. Crop and soil-process modeller also has limitation of integrating these phenomena in the mechanistic growth models. Most of the dynamic models in the globe deal with one nutrient at a time. The basic framework of logistic evolution of customized fertilizer grades, as a currently under development have three primary components:

- Defining fertility management zones
- Using empirical models like QUEFTS/STCR
- Use secondary research data and experiential learning's

Eligibility criteria for manufacture and sale of customized fertilizers

Permission for manufacture and sale of customized fertilizers shall be granted to only such manufacturing companies whose annual turnover is Rs.500 crores and above. Manufacturing companies should have soil testing facility with an annual analysing capacity of 10,000 samples per annum for NPK, secondary and micro nutrients. Such laboratory must possess the requisite instrument viz., Atomic Absorption Spectrophotometer, Flame Photometer, pH meter,

Conductivity Bridge, Kjeldhal Distillation etc. The grades of customized fertilizers, which company will manufacture, must be based on scientific data obtained from area-specific, soil-specific and crop specific and soil testing results.

The manufacturing companies, in association with agricultural universities/KVKs concerned, should also conduct agronomy tests of the proposed grade to establish its agronomic efficacy. Such manufacturing companies should generate multi-location trials (not on farm demonstrations) on different crops for minimum one season. Such manufacturing companies must draw these soil samples from within its operational areas and should also ensure that minimum one sample is necessarily, drawn from University/ State government may also be used to prepare soil fertility map and for determination of required soil, area, and crop specific grades for existing and potential marketing areas.

Grant of permission to manufacture

Subject to the fulfillment of eligibility criteria referred to in the preceding paragraphs, the permission for the manufacture and sale of Customized Fertilizers will be granted by Joint Secretary (INM), Department of Agriculture and Cooperation, MOA, GOI. Such permission, for manufacture and sale of particular customized fertilizer grade shall be granted only for the specific area and for a period not exceeding three years. Such manufacturing companies must start their manufacturing and sales process with in a period of six months from the date of grant of such permission. For grant of permission to produce and to sell such customized fertilizers, the concerned manufacturing companies should necessarily apply for permission, to the office of the Joint Secretary (INM), Ministry of Agriculture under intimation to the State Government in the prescribed Performa as provided in annexure II. The competent authority shall expedite the requisite permission authorization of otherwise within 45 days of the receipt of such applications

Application for grant of permission for manufacture of customized fertilizer

1. Name of the Company and address
2. Location of the unit where the customized grade of fertilizer proposed to be manufactured
3. Annual Turn over of the company
4. Location/Particular of the Area where the customized fertilizer is to be introduced
5. Soil Fertility Status of the Area
6. Introduction Season
7. Cropping Pattern of the Area
8. Soil PH
9. Irrigated or unirrigated land
10. Location of soil testing lab
11. Annual Analyzing Capacity of soil samples
12. Area Climate
13. Grades and other details relating to composition of customized fertilizer
14. Raw Material(indicate whether the subsidized material to be used)
15. Quantity to be produced in each season
16. MRP
17. Whether the company possess any permission for manufacturing the grades of customized fertilizer in any area

Renewal and revision of customized fertilizer grades

On completion of three years or earlier, manufacturing

company of customized fertilizers shall submit a renewal/revision application for varied customized fertilizers manufactured by it. In case, no change in the already approved composition of customized fertilizers is required, the same shall also be declared by the manufacturer. The competent authority, shall, thereon, accord its approval within a period of 45 days from the date of receipt of such applications, failing which the duly acknowledge copy of such application shall be treated as official approval.

Manufacturing methodologies

Fertilizers industry is a form of secondary chemical production. There are basically three options ((MAIDC, 2014)) from the simplest to the more complex i.e.

- Bulk Blending
- Compound Granulation/Steam Granulation and
- Complex/Chemical Granulation

Chemical granulation

Chemical granulation is also called 'slurry granulation' or 'complex granulation. Here fertilizer production start with the basic raw materials like rock phosphate, acids and ammonia rather than their salts like diammonium phosphate and urea. So large capacity plants are needed to carry out chemical reactions. Infrastructure cost of handling and storage of acids and ammonia are huge here. Because of the difficulty in undertaking chemical reactions it is less flexible to produce variety of grades.

Bulk blending

Most simplest and cheapest option available for the production of CF, which involves pure mixing of solid fertilizers in a ratio required to get the desired nutrient ratio. It only requires warehouse, weighing and mixing equipment. It has the advantage of smaller capacities of decentralized production uniquely suited to give the customer exactly the NPK ratio he requires. The physical standard should be such that the shape and size of all fertilizers, raw materials, which are to be used in bulk blends, are similar and also high quality granular fertilizer material is needed. In Indian context importing of the raw materials is needed because of these stringent specifications of raw materials, and for large scale production it is not suitable. But for the experimental purposes this is the most suitable method. (FAI, 2011)

Compaction

Compaction is also called as 'dry granulation' process as not using any liquid binders for making it as granule. Fertilizer material should be powdered and apply high pressure on this powdered materials to squeeze them together which results in large dust generation and the final products in the form of briquettes or flakes.

Fluid method

Most suitable method in the intensive farming system to obtain a higher yield. Two types of liquid formulations, clear liquids and suspension liquids. If it is suspension liquids it needs constant agitation. It provides a dust free application method. Mixtures of ammonia, phosphoric acid and micronutrients gives a good homogenous liquid fertilizer.

Compound/Steam granulation

Raw materials are in solid form and uniform size reduction of this fertilizer material is the key to granulation. Agglomeration of granules can be attained by use of hot water

or low pressure steam. Then the granulated materials should be dried and cooled by dehumidified air. Hygroscopic products like urea containing grades need dehumidified bagging plant also otherwise caking of the products will occur. This is the most suitable method for the large scale production of customized fertilizers in India.

Customized fertilizer formulation

Fertilizer association of India is recommending certain specifications for a particular grade of formulation. For basal application it should be granular in size with minimum 90 percent materials remains between 1-4 mm Indian standard sieve and size less than 1mm should not exceed 5 percent and the product should not exceed 1.5 percent. Foliar application grades should be 100 percent water soluble. Minimum nutrient content in the grade should be 30 units of all the nutrients combined.

Customized formulations available in India

There are about 36 formulations approved by fertilizer control order of India. The important companies in the market producing customized fertilizers are Tata Chemicals Ltd., Deepak Fertilizers, Nagarjuna Fertilizers, Coromandel Industries Ltd. etc. A customized fertilizer plant of 400 metric tonnes capacity per day and constructed within the existing premises of NFCL was commissioned. Integrated with soil information, the customized fertiliser is formulated on sound plant nutrition principles, thus becoming soil and crop-specific fertilizer.

Tata Chemicals Ltd (TCL), launched the 'Paras Farmoola', the country's first ever customized fertilizer product specifically targeted at farmers in western-central Uttar Pradesh (UP). For manufacturing the customized fertilizers, TCL has set up an Rs 60-crore 130,000 tonnes per annum facility at its existing urea unit at Babrala in UP, with technology sourced from A.J. Sackett of the US. The company intends to establish two more plants, involving a total outlay of Rs 110 crore, in West Bengal and UP.

Information available and what has been done in developing customized fertilisers

Presently about 80 formulation having N, NP, NPK, NPKS are available in the country depending upon crops and regions. Development of customized fertilizers like zincated urea and boronated super phosphate in early period did not catch up popularity among the farmers-due to predominance of single micronutrient deficiencies, high cost and fear of toxicities due to their indiscriminate use. Even now farmers prefer to use straight sulphate salts of micronutrients like zinc, iron, and manganese compared to Zn or B fortified fertilizers. Foliar spray method for applying iron and manganese is found more efficient than soil application (Nayyar, 1990) ^[7], so blending of iron and manganese fertilizers with N/NP/NPK may not prove beneficial. High cost is another issue for developing customized fertilizers.

Blending of bentonite sulphur with NP NPK is found helpful in increasing oil seed and pulse crop yield but it proved Costly than locally available cheaper sources like gypsum and single super phosphate (Singh, 2007) ^[17].

Application of customized or specialty fertilizers in horticultural and vegetable crops is widely practiced either for soil, foliar application or in fertigation. Development of localized specific soil and crop need based customized fertilizer may prove beneficial in achieving balanced nutrition of crops. Suitable government policies to favour better pricing

for specific customized fertilizer having balanced use of zinc, boron, sulphur is highly appreciated to prevent malnutrition in livestock and people of the India.

Customized fertilizer grades

The grades of customized fertilizer which the manufacturing company propose to manufacture and sell, shall be based on area specific and crop specific soil testing results. The manufacturer may be in association with Agricultural Universities/KVKs concerned, shall also conduct agronomy tests of the proposed grade to establish its agronomic efficacy. The manufacturing company, preferably in association with concerned agriculture universities/KVKs may continue to conduct agronomy tests of the proposed grades on the farm, for at least one season. The minimum nutrient contents in a specific grade of customized fertilizer, proposed to be manufactured, shall contain not less than 30 units of all nutrients, combined.

Quality of customized fertilizers

The Customized Fertilizers to be used for based application shall be granular in size with minimum 90% between 1-4 mm IS sieve and Below 1mm should not exceed 5%. The moisture content should not exceed 1.5%. For foliar applications, however, the grades should be 100% water soluble. The specifications of the customized fertilizers provided by the company to manufacture of customized fertilizer, duly approved by the Ministry, shall be strictly adhered to.

Quality check

(i) Procedure for draw of sample of fertilizers

- a. The method of drawing samples shall be provided in the FCO.
- b. Clause 4A (iii) Weight of one sample should be 400g. as specified under Clause 4 A (iii) for Part A in Schedule 1 of the FCO, 1985.

(ii) Methods of analysis of fertilizer

- a. The methods of analysis of fertilizers shall be as per the procedure prescribed in FCO.
- b. For preparation of sample for analysis in the laboratory (Clause 1-1) under part B in schedule II of FCO, 1985 the whole sample size of 400g should be powdered. The whole sample size of 400 g shall be powdered.

(iii) Tolerance limit

The tolerance limits prescribed under the FCO, 1985 for NPK mixture and NPK with micronutrients, shall be applicable to the customized fertilizers. However such tolerance limit shall not exceed 3% for all nutrients particularly when secondary and micronutrients are also present with NPK.

Labeling

1. The word Customized Fertilizer shall be super scribed on the bags.
2. The name of the crop and geographical area for which the customized fertilizer recommended shall also be indicated on the bags.
3. The grades of Customized Fertilizer and the nutrient contents shall be mentioned on the bags.
4. The manufacture should preferably have tampered proof bagging so as to check on adulteration.

Pricing of customized fertilizer

The Company shall fix reasonable MRP for its approved grade of customized fertilizers taking all factors into consideration.

Customized fertilizer for higher crop productivity

Fertilizer is an essential key input for production and productivity of crops. Fertilizer alone contributes towards 55% of additional food production. Since there is no scope for extending the cultivable area, more productivity per unit area is the only option and fertilizer is the main cart puller. (Tiwari, 2014) ^[20] Custom mixed fertilizer is a mixed fertilizer formulated according to individual specifications furnished by the consumer before mixing. Some land needs much higher quantities of balanced fertilizer mixtures in granulated form, for soil application; water soluble form for drip irrigation, mini sprinkler and foliar spray systems. Customized fertilizer may also be defined as multi-nutrient carrier which contains macro and/or micronutrient, whose sources are from inorganic or organic, which are manufactured through systemic process of granulation and satisfies crop's nutritional demand, specific to area, soil and growth stage of plant. Customized fertilizers are enriched with both macro and micro nutrients and are manufactured through a systemic process of granulation with stringent quality checks.

Application

The objective behind the customized fertilizer is to provide site specific nutrient management for achieving maximum fertilizer use efficiency for the applied nutrient in a cost effective manner. The customized fertilizer may be combination of nutrients, secondary nutrients and micronutrients. Customised fertilizers are combination of micro nutrients like sulphur, zinc, boron added to the key items such as urea and diammonium phosphate (DAP) and potash, in a proportion that suits specific crops and soil patterns. A fertilizer formulated according to specifications that are furnished by/for a consumer prior to mixing, usually based on the results of soil tests. Customized fertilizers are depends on soil, crop, water and specific nutrients. Customised fertiliser manufacture basically involves mixing and crushing of urea, DAP, MOP, ZnS, bentonite sulphur and boron granules for obtaining the desired proportion of N, P, K, S and micronutrients. The mixture is subjected to steam injection, drying, sieving and cooling, so as to get a uniform product with every grain having the same nutrient composition. The sharp rise in fertilizer prices emphasizes the need for more research to improve the efficiency of fertilizer use. Corporate social obligation to continue to help farmers in India, get higher yields with less fertilizer i.e. by Integrated Soil Fertility Management (ISFM) as a tool to improve the efficiency of fertilizer for increased profitability of small holder farmers of India

Benefits

Customized fertilizers is use of the Fertilizers Best Management Practices & are generally assumed to maximize crop yields while minimizing unwanted impacts on the environment & human health.

- Fertilizer Best Management Practices will make it "easier" in "future" for farmers, extension agents, crop advisers & researchers to exchange their experiences and also to restrict the unwanted nutrient impact on the ecosystem.

- Application of customized fertilizer is compatible with existing farmers system & hence it will be comfortably accepted by the farmers.
- Production of customized fertilizers will ensure improved 'Fertilizer Use Efficiency' & creating a new "Virtual" source of nutrients – implying from the existing quantity of DAP, MOP, Urea, SSP & A.S available & consumed in India, the agricultural produce output will increase, simultaneously the distribution & availability of fertilizer will be better. All this is achievable keeping the subsidy allocation constant.
- Customized fertilizer satisfies crop's nutritional demand, specific to area, soil, and growth stage of plant.
- As the micronutrients are also added with the granulated NPK fertilizer the plants can absorb the micronutrient along with macronutrient which prevents nutrient deficiency in plant.
- Mixed fertilizers with micronutrients provide recommended micronutrient rates for the agricultural field at the usual fertilizer application.
- The farmer need not buy micronutrient separately at extra cost, thus reducing the total cost. It is found that incorporation of micronutrient with granular fertilizer at the time of manufacturing results in uniform distribution of micronutrient throughout granular NPK fertilizer.

This is because micronutrient source is in contact with the mixed fertilizer under the condition of high moisture and temperature. Micronutrient with the mixed fertilizer is one of the most convenient methods of fertilizer application and helps in more uniform distribution of nutrient with conventional application equipment. It is a very unique method developed in agriculture industry and has tremendous scope for future.

Customized fertilizers for Site Specific Nutrient Management (SSNM)

Nutrient management is a major component of a soil and crop management systems. Site specific nutrient management is applying those concepts to areas within a field that are known to require different management options can be applied to any field and any crop. While most often thought of a relation to use of computer and satellite technology, the site-specific nutrient management does not require special equipment, and does not require a large farming operation. The technology tools certainly expand the capabilities for using site-specific management. It is basically a systematic approach to apply sound agronomic management to small areas of a field that can be identified as needing special treatment. The components of site-specific management to small areas may not be new, but now we have the capability with new technology to use them more effectively. Site specific management includes practices that have been previously associated with Maximum Economic Yield (MEY) management, best management practices (BMPs), as well as general agronomic principles.

Priority areas for customized fertilizers

The introduction of SSNM strategies should start with the priority areas facing one or more of the following problems:

- Areas having inadequate or unbalanced use of fertilizer nutrients with low yield levels.
- Areas with crops showing nutrient deficiency symptoms at large scale.

- Areas with occurrence of pest problems linked to nutrient imbalance or overuse of fertilizer N.
- Areas with inefficient fertilizer N use at higher rates (no proper splitting and timings) with insufficient use
- Areas having evidence of multi-nutrient deficiencies including secondary and micronutrients in soils and crops.

Approach

The promotion of customized fertilizers aims at increasing farmers' profit by achieving the goal of maximum economic yield (MEY) of crops. The main features of customized fertilizers are:

- Application of nitrogen, phosphorus, and potassium fertilizer is adjusted to the location- and season-specific needs to the crop.
- Site-specific application of secondary and micronutrients based on soil tests are followed.
- Promotion of customized fertilizers should also provide guidelines for selection of the most economic combinations of nutrients.
- Promotion of customized fertilizers should also ensure recommendations for wise and optimal use of existing indigenous nutrient sources such as crop residues and manures.
- Customized fertilizers to be effective should ensure adoption of all the components of integrated crop management (ICM) viz. the use of quality seeds. Optimum plant density. Integrated pest management, and good water management.

Major constraints to promote customized fertilizers

The available research information sounds well for upward revision of fertilizer recommendations as the existing fertilizer doses (NPK) are proving to be sub-optimal for maximum economic yield. It is also evident that application of nutrients according to current recommendations is causing nutrient depletion particularly in respect of potassium and micronutrients.

The current soil test based recommendations consider only the nutrient deficiency magnitude, not the yield targets. Only one recommendation being currently given without considering the yield target is proving to be sub-optimal for higher yield targets, thus farmers are loosing yield, produce quality and profits. The current fertilizer recommendations support only medium yield target provided the supply of nutrients other than NPK is not a limiting factor. In contrast, the deficiency of one or the other secondary and / or micronutrient deficiency is observed in all parts of the country.

As on date, soil testing laboratories in India do not make recommendations for secondary and micronutrients, because they do not analyse general soil samples of these nutrients. The deficiencies of secondary and micronutrient in majority of the cases are constraining crop performance resulting in low yield, poor crop quality low nutrient use-efficiency of the applied fertilizers and also causing threat to environment.

All the nutrients, which soil cannot be applied. PPIC-India Program's current research thrust has generated good deal of information on this issue.

After awareness about correct balanced fertilization, the availability of materials to supply all the needed nutrients would be a great challenge for industry and the policy makers. But ensured supply of the nutrients other than NPK would be essential and inevitable for sustainable high yield agriculture.

The customized fertilizers to be effective under actual field conditions, the basic need is the complete overhauling of soil testing service in respect of quality, soil fertility ratings and also in respect of the so called 'optimum' fertilizer recommendations which are proving to be sub-optimal' for maximum economic yield. The fertilizer recommendations should take care all the existing nutrient deficiencies to meet customer's fields and crops demand. The fertilizer recommendations should be enlarged both in respect of number and quantities of nutrients. Well beyond NPK. The nutrient use through customized fertilizers on the principles of SSNM should also accommodate a wide range of socio-economic variations, including those situations of labour shortage. Efficient N management may also result in off farm environmental benefits through a reduction in yield especially in situations where N inputs are large compared to other nutrients, which may increase profitability.

Achieving the goal of yield maximization through customized fertilizers

As stated earlier, the potential yields of crops have not yet been realized in India and emphasis is being laid on increasing food grain production by adoption of improved agro-techniques and optimum utilization of production inputs. To sustain the momentum of this objective, collaborative field on-farm trails /demonstrations should be conducted by the scientists and fertilizer industry personnel to evaluate the effect of customized fertilizers for higher yields. The scientists and the industry personnel should ensure providing the technology for continued higher yields.

Technology transfer

When technology is generated or is put together, its correct dissemination is extremely important. Greater focus is required on:

1. Target group oriented activities.
2. Production and distribution of literature in local languages.
3. Greater interaction with district level government / extension / industry staff.
4. Orientation or briefing sessions on the MEY technology with district level officers of the state departments of agriculture and horticulture.
5. Developing video cassettes / CDs on balanced nutrient application including pictures of Deficiency symptoms.

On-farm trials

Fertilizer use development requires teamwork through collective and coordinated effort of several agencies involved in research, extension and input supply. In the larger context even agencies providing irrigation, credit energy and produce markets are also important because fertilizer use is a means to increase crop productivity leads which in turn to a marketable surplus, which can be sold by the farmers to increase their incomes and standard of living. Fertilizer use thus has a direct effect on raising the living standard of the rural population.

Effects on crop production

Concept of customized fertilizers may be new in India but it is common in agriculturally advanced countries. This shows the need for realization of the importance of CF by our government for attaining the food and nutritional security. Even though the production of customized fertilizers is difficult, the end is very promising. This can be substantiated by studying its performance on farmer's field.

Performance of CF at farmers' field

Singh *et al.*, 2012 reported that study was conducted by Tata chemicals Ltd. in Noida to know the effect of customized fertilizers in farmers field. Here they compared the yield from customized fertilizers and the yield from common farmer practice. They got 14%, 20%, 15% and 40% increase in yield of rice, wheat, potato, and sugarcane respectively over the common farmer practice. They are saying that it has been heartening to observe that farmer using lower dose of customized fertilizer also got superior performance over their conventional practice.

Effect of nutrient management practices on castor-sorghum cropping system

Experiment conducted at Directorate of oil seed research, Hyderabad by Ramesh *et al.* in 2013 to study the effect of nutrient management practices like recommended dose of fertilizers (RDF), integrated nutrient management(INM), organic nutrient management(ONM), fertilizers based on soil test crop response(STCR) and customized fertilizers(CF) on the productivity and economic return of castor-sorghum cropping system.

Effect of nutrient management practices on yield attributes and economic returns

Application of customized fertilizers recorded significantly higher yield attributing characters compared to other nutrient management practices both in case of castor and sorghum. But were comparable with the treatment receiving fertilizers based on STCR resulted in about 18 and 15% increase compared to RDF and so system income and B:C ratio was also maximum in CF followed by STCR. CF recorded the highest uptake of nutrients in cropping system compared to RDF. Higher seed yields of castor and sorghum with customized fertilizers or STCR was due to favourable crop growth and higher yield attributing character. In these treatments, nutrients are applied in proportion to the magnitude of deficiency of a particular nutrient and the correction of nutrient imbalances in soil helps in harness the synergistic effects of balanced fertilizer application (Ramesh *et al.*, 2013) ^[11].

Effect of customized fertilizers on no. of productive tillers, panicle length and no. of filled grains per panicle and grain yield of rice (var.ADT.43) (Kaleeswari, 2013) ^[3]

The pooled analysis of two locations indicated that application of 100% RDF in the form of CF II increased the productive tillers (21 nos.), panicle length (27.70 cm) and number of filled grains per panicle (203 nos.).The number of productive tillers recorded in the treatment that received 100 % RDF in the form of CF II was on par with 100 % RDF through CF I +25 kg Zn SO₄ ha⁻¹ and 100% RDF through straight fertilizers. The lowest number of productive tillers, panicle length and number of filled grains per panicle were recorded in the treatment that received 50 % RDF through CF I +25 kg Zn SO₄ha⁻¹.Successive increase in fertilizer levels from 50% RDF to 100% RDF had marked influence on the yield attributes of rice.

Application of 100% RDF of straight fertilizers recorded a grain yield of 5628 kg ha⁻¹. Application of 100% RDF in the form of CF II recorded the highest grain yield of 6878 kg ha⁻¹ followed by the application of 100 % RDF as CF I + 25 kg Zn SO₄ ha⁻¹ (6622 kg ha⁻¹). The lowest yield of 5061 kg ha⁻¹ was recorded with the application of 50 % RDF in the form of CF I+ 25 kg Zn SO₄ ha⁻¹.Yadav *et al.* (1998) showed that

significant yield decline in rice in the treatments with imbalanced application of N, P and K fertilizers.

An increase in yield of 15.1 per cent over the application of 100 % RDF of straight fertilizers was obtained with the application of 75% RDF through CF II. Application of 100 % RDF through CF II registered an increase in yield of 22.2 per cent over the application of straight fertilizers. This could be attributed to the addition of Zn increased the number of tillers and reduced the spikelet sterility. These results were in concurrent with the findings of Buri *et al.* (2000). The increase in grain yield over the application of straight fertilizers was 11.1 per cent in the treatment that received 75% RDF in the form of CF I + 25 kg Zn SO₄ ha⁻¹. Application of 100 % RDF as CF I + 25 kg Zn SO₄ ha⁻¹ registered an increase in yield of 17.7 per cent over the application of straight fertilizers. Balanced fertilization strategy enhanced the rice yield as compared to the conventional method of nutrient addition through straight fertilizers. Similar results were reported by Khalid *et al.* (2003)^[6].

Effect of customized fertilizer on nutrient uptake (NPKS & Zn) of wheat (*Triticum avestivum*) crop (2 year pooled data)

The maximum uptake of N (117.3 kg/), P (21.4 kg/ha), K (150.5 kg/ha), S (96.1 kg/ha) and Zn (229.9 g/ha) were observed under 150% dose of CF (T6) which is statistically significant due to different doses of customized fertilizer. These results agree with the findings of Sharshar and Said (2000) revealed that the optimum NPK fertilizer enhanced growth and yield and nutrient uptake in wheat. The higher nutrient uptake was mainly due to higher biological (straw+ grain) yield. Pandey *et al.* (2007)^[8] also reported similar findings. Application of customized fertilizer helps to provide essential nutrient to get the targeted yield. This shows that NPKS and Zn combination is useful for wheat growth and yield. Singh (2006)^[16] and Das *et al.* (2003)^[1] also reported similar findings for N, P, K, S and Zn (Sharshar and Said, 2000)^[14]

Chemical composition of mulberry garden soil as influenced by CF on 75 th day after pruning

The availability of soil NPK in the mulberry garden was increased due to application of 150% nutrients through CF (T6) which recorded maximum available NP₂O₅, K₂O of 282.84, 78.09 and 281.04 kg/ha, over other treatments. The next best treatment was T5(274.93N, 76.69 P and 261.27K kg/ha) respectively. (Sadatulla and Shyla, 2013)^[13].

Influence of customized fertilizers on yield and economics of finger millet

Significant differences in the yield of both grain and straw of finger millet were observed due to use of different doses of customized fertilizer. Highest grain and straw yield of 3279 and 4510 kg/ha, respectively were recorded in 150% customized fertilizer dose and was on par with 125% customized fertilizer dose (3227 and 4438 kg/ha) and 100% customized fertilizer dose (3031 and 4249 kg/ha, respectively). RDF as per package of practice recorded on par grain and straw yield (2138 and 3102 kg/ha, respectively) with 50% customized fertilizer dose (2130 and 3007 kg/ha, respectively). This was due to the fact that the crop has not experienced nutrient stress at any growth stage because of balanced nutrition and improved vegetative growth and growth parameters such as total dry matter production and

increased number of tillers resulted in good grain yield. Similar results have been reported by Kavalappa (1989)^[5].

Effect of customized fertilizers on the performance of potato

A field experiment was conducted during Rabi season of 2010-11 at Agronomy Research Farm, Narendra Deva University of Agriculture & Technology (Narendra Nagar), Kumarganj, Faizabad. The treatments are 6 customized fertilizers having nutrients i.e. N,P,K,Zn,B, and S. Results of the study indicated that Initial and final plant stand were non-significant under various customized fertilizer. Yield attributes viz. total number, weight (grade wise), total weight of tubers hill⁻¹, plot⁻¹ and ha⁻¹ were recorded significantly higher under customized fertilizer F4 which was statistically at par with F6 and superior over rest of the customized fertilizers. Quality parameters viz. specific gravity, dry matter and starch content did not influenced significantly due to effect of customized fertilizers. The suitable customized fertilizer for potato crop was found to be F4-8 : 18 : 26 : 1 : 0.1 : 6 (N:P:K:Zn:B:S kg ha⁻¹ 150 : 67.5 : 97.5 : 3.75 : 0.37 : 22.5). (Irfan, 2015)^[2].

Effect of customized fertilizers on yield and micronutrients contents of okra grown on Typic Ustochrepts soils of Anand

A field experiment was conducted on Typic Ustochrepts soils at the College Agronomy Farm, BACA, Anand Agricultural University, Anand, Gujarat, India, during the period 2000-03 to study the efficacy of customized fertilizers in improving crop production of okra. Okra yield increased significantly due to foliar treatment, i.e. micronutrient mixture grade-IV (for Fe and Zn deficiency), soil application of mixture Grade-V and also due to soil application of FeSO₄ at 15 kg/ha and ZnSO₄ at 8 kg/ha as per soil test value. The soil application of multi-micronutrients mixture grade-V was found beneficial and economical in increasing okra yield (Patel *et al.*, 2008)

Effect of different levels of customized fertilizer on soil nutrient availability, yield and economics of onion

A field experiment was conducted to study the effect of different levels of customized fertilizer (CF) on soil nutrient availability, yield and economics of onion. The results revealed that the significantly highest plant height (57.77cm), stem diameter (6.03cm) and bulb diameter (15.13cm) at the time of harvest, fertilizer use efficiency, bulb yield (22.34 t ha⁻¹) and B:C ratio (2.56) of onion were recorded in 100 % recommended dose of NPK through CF in three equal split doses. The significantly highest available nitrogen (213 kg ha⁻¹), phosphorus (14.42 kg ha⁻¹) were recorded in 125 % recommended dose of NPK through CF in two equal split doses and available K (804 kg ha⁻¹) in 100 % recommended dose of NPK through CF in three equal split doses over the rest of the other treatments. The application of 100% recommended dose of fertilizer (100:50:50 N:P₂O₅:K₂O kg ha⁻¹) either two or three splits through CF to onion appears to be improving soil fertility, yield and yield contributing character of onion and getting higher net monetary returns. (Kamble and Kathmale, 2015)^[4].

Marketing opportunities

Liberal provisions of customized fertilizers guidelines issued by Government of India present an opportunity to the segment of fertilizer industry and competent entrepreneurs. For this segment of industries having fiscal and technological

capabilities, it is possible to set high standard of production and marketing for the benefits of farmers. These standards are to be strictly followed. Notwithstanding there can be challenging time for the Government and the customized fertilizers industry for the development of policy guidelines to ensure its adherence. In terms of economic value, only those customized fertilizers will survive in the market, which will “add value” to farmers. Once this objective is achieved, it will be easy for customized fertilizers manufacturer to command premium pricing over and above conventional fertilizers. The time will show that the customized fertilizers will hold on to the margins while the conventional fertilizers will continue to suffer from erosion of margin. Global experience shows two vital things; one there is vital policy support for the customized fertilizers industry and two there is high level technology support for the manufacture of quality products. In agriculturally advanced countries, more than 50 per cent of fertilizer is used in the form of customized fertilizers. In China, who is first in agriculture production is fully customized fertilizer dependent. In India different grades of NPK are used which account for 15 per cent or less of consumption (Rakshit *et al.*, 2012) ^[10]. This justifies that customized fertilizers are the future fertilizers for country like India as it improves fertilizers use efficiency.

Challenges

Government have to stop non-serious players to evade the guidelines and exploit it when fertilizer supplies are scarce. The risk for the customized fertilizers industry, however, lies in making heavy capital investment in state of the art manufacturing facility for the customized fertilizer. This is because there is no long-term assurance from the government to keep the policy intact throughout the years. Most likely in the situation of shortage situation government may disallow use of subsidized fertilizers for manufacturing customized fertilizers. This could make the investment in the manufacturing plant unviable and thus redundant. More research is needed to develop CF according to soil type for same crop as the deficiency of all nutrients does not in all soil in a similar way.

Future plan

Precise global positioning system (GPS) based information for soil fertility mapping to suggest nature and extent of deficiency of major micro and secondary nutrients. Assessment for indigenous sources for nutrient supply which farmers are practicing. Identifying most wide spread crop, cropping system dominant in a given zone area. Deciding yield target which are possible to achieve, economical and beneficial based on market and social consideration. Validation of NPK prescription for expected biological response before developing customize: formulation. Advancement brought in new fertilizer over existing fertilizers attract farmers.

Conclusion

Customized fertilizer is to promote site specific nutrient management with a view to achieve the maximum fertilizer use efficiency of applied nutrient in a cost effective manner. It is clear that customized fertilizer is no doubt a marker in fertilizer revolution which may aggravate the scope of Site Specific Nutrient Management and Precision Agriculture. The customized fertilizer may include the combination of nutrient based on soil testing and requirement of crop and the formulation may be of primary, secondary and micro-

nutrients. Innovative product like customized fertilizers specific to agro climatic conditions can be offered to the farmers to remediate nutrient deficiency particularly secondary and micronutrients for popularize the concept. It is the time to provide incentives to farmers using 100% water soluble fertilizers in view of quality produce. It is clear that customized fertilizer using farmer would not have to buy different fertilizers or worry about the quantity of fertilizer to be added. So the product would provide a simplest approach for the fertilizer application to the farmers.

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