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BALANCED NUTRIENT FERTILISATION: AN APPROACH FOR AGRICULTURAL SUSTAINABILITY

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The green revolution was the thumping milestone for self-reliance in the food security of the country. Major contributing factors in this green revolution involved high yield varieties, fertilisers, and the irrigated area's expansion. Those high yielding varieties were highly responsive to the added nitrogenous fertiliser, which led to higher production. Indian soils were fertilised with organic manures and farmyard manures during that era which stabilises soil health. However, with the beginning of intensive cultivation, the nutrient status of the Indian soils started depleting. The application of nutrient fertilisers shows synergistic and antagonistic effects on plants growth, development and crop yields. The synergistic effects of the different nutrients lead to higher uptake of other useful nutrients. The antagonistic effect shows the detrimental effect of an applied nutrient on the uptake of the other nutrients. The lack of established nutrient management strategies and poor knowledge of the farmers pertaining to balanced nutrient fertilisation were the two critical factors for declining productivity under intensive cultivation. For most of the Indian soils, ideal nutrient application ratio of N: P_2O_5:$K_2O$is 4:2:1; this gap widens from 4.7:2.3:1 in 2010-11 to 6.6:2.6:1 in 2018-19(FAI, 2019). The ratio is indicating that the nutrient imbalance is increasing in Indian soils. Apart from the imbalanced NPK fertiliser applications and less use of farmyard manure or compost causes multiple nutrient deficiencies, which includes P, K, S, Zn, Mo, Fe and Mn in different parts of the country.

Fig 1: Nutrient deficiency in wheat plants due to imbalanced fertilizer application

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Balanced fertilisation

In a particular agro-climatic condition, the application of plant nutrients in optimum quantities with appropriate method and appropriate time to meet the demand of the specific crop for its optimum growth, development, and productivity can be termed as **balanced nutrient fertilisation**. Balanced nutrient fertilisation improves the soil's physical, chemical, and biological environment, whereas underbalanced nutrient fertilisation leads to soil sickness and the uneconomic waste of scarce resources. For a sustainable and productive land-use system, balanced nutrient fertilisation is essential for continuous food grain production.

Concept of Balanced Nutrient Fertilisation

In 1840, Justus von Liebig introduced the term **balanced fertilisation** which was mainly based on minimum law. According to this law, the plants' growth and development depend on the amount of the nutrients whose quantity is less than the plant's requirement keeping all other essential nutrients in optimum amount. Hence, balanced nutrient fertilisation is not limited to the application of NPK fertilisers only. It also includes the application of farmyard manure/organic manures to meet the demand of other essential nutrients by the crop plants to ensure:

- Efficient use of applied fertiliser
- Development of the best positive and synergistic interactions amongst the various other factors of production.
- For improving/ sustaining the soil productivity.
- Minimising the difference between potential yield and actual yield of a crop variety.
- Minimising environmental pollution.

Effect of Unbalanced nutrient fertilisation on agriculture

The adverse effects of unbalanced nutrient fertilisation can be broadly divided into three groups:

1) Effect on soil fertility
2) Effect on crop productivity
3) Effect on animal productivity and health

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1) ***Effect on soil fertility***

The unbalanced nutrient fertilisation induces deficiencies and toxicity of nutrients in the soil in response to positive and negative interactions between the nutrients, according to Annual Reports on AICRP-IFS under the different nutrient management practices. The fertility status of the soils was in declining order after 25-30 years after intensive cultivation. In different soil, increased deficiency of P, K, S, Zn and Mn were reported. Several researchers documented that increased application of phosphorus induces iron deficiency; increased application of zinc induces iron deficiency or vice-versa. In some acidic soils, excess ammonical fertilisers promote the protons release in soil solution through plants. Thereby, the growth medium becomes more acidic with more iron availability for the plants, which may cause iron toxicity. Nitrate fertilisers increase the pH of the soil, which leads to the deficiency of iron for plants. Balanced fertilisation also affects the soil microbial population.

2) ***Effect on crop productivity***

The different nutrient plays different roles in improving crop productivity. Nitrogen imparts soft tissue, and potassium imparts disease resistance to the plant. Excess nitrogen applications lead to more softness in plants, whereas low potassium application results in a decline in disease resistance in plants, which makes more favourable conditions for fungal infection and insect infestation, which ultimately results in reduced crop productivity. Lack of micronutrients in the soil for the crops results in stunted growth, twisting/curling of the leaves etc., which in turn affect the plants' photosynthetic potential. This reduction in photosynthesis leads to a reduction in crop productivity.

3) ***Effect on animal productivity and health***

The agricultural animal, which includes cows, buffalos, sheep, goats, pigs, and poultry, primarily depends upon crops for their feed and fodder requirements. The cultivated fodder and feed from the nutrient-deficient soils could not supply adequate nutrients and minerals to animals. For example, the deficiency of calcium or phosphorus in the feed and fodder may weaken the bones of the animals. Again, low potassium in feed/ fodder of animals may disturb water balance, osmotic pressure, acid-base balance, activations of the enzymes,

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metabolising carbohydrates and proteins, and neuromuscular regulation activity (along with Ca) and also the regulation of heartbeat. In some cases, lack of adequate nutrient balance in animal rations leads to infertility and poor health in productive animals.

Role of Balanced Fertilisation

Balanced fertilisation improves the physical, chemical, and biological environment of the soil, increasing crop yields. It also plays a significant role in making plants more tolerant to drought, cold, insects, pests and diseases. In recent years, balanced fertilisation increased wheat and corn yields in China by 15-20% (Cisse, 2007). Besides optimum crop production and better food quality, balanced fertilisation is the best solution to minimise the risk of nutrient losses. If applied nutrients are not balanced, the crop will not show its proper growth, and the overall uptake of nutrients will be affected. Thus, the applied nutrient will not be adequately utilised by the crops. They will be accumulated in the soil, which leads to environmental problems. Balanced fertilised crops provide an adequate amount of nutrients for the livestock, which improves their health and productivity. Balanced fertilisation is a sustainable approach to get maximum economic benefits from high crop yields with efficient soil nutrient reserves maintenance.

Benefits of Balanced Fertilisation

1. Balanced fertilisation improves and enhances soil fertility by replenishing the nutrient in the soil.
2. Combined organic and inorganic fertilisers can only take potential benefits from high yielding varieties approach in a balanced manner. High yielding varieties cannot produce satisfactorily without the use of proper doses of nutrients. Studies confirmed that in the green revolution, the contribution of varieties also increased rice yield was 27 Mt, and the fertiliser contribution was 29 Mt (Pinstrup-Anderson and Hazell, 1985).
3. Balanced fertilisation increase the yield and biomass production of crops in nutrient-poor soils of tropical areas. Additional biomass can be incorporated into the soil to improve organic matter content, significantly improving soil moisture retention capacity and enhancing nutrient use efficiency. Thus in nutrient-poor soils, balanced fertilisation can create a 'win- win' situation by increasing food production and reducing soil degradation.

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4. Indian soils are mainly deficient in S, Zn and B, and if these nutrients are applied adequately in soil, then the efficiency of NPK will also be increased significantly (Sakal*et al.*, 2006).

How to Make Use of Balanced Fertilisation

1) Applications of the recommended dose of fertilisers

Three concepts are used for making fertiliser recommendations,*i.e.*, Maintenance concept, Cation-Saturation ratio and Sufficiency level. Among the three of them, the sufficiency level concept is followed mostly for fertiliser recommendations. Insufficiency level concept, crop response is considered for applying nutrients for the crops. Fertiliser recommendations also vary with different varieties of the same crop. Therefore, fertiliser recommendations are also provided with the package and practices of newly released varieties. Some general recommended dose of nutrients for different crops is given in Table 1.

Table 1: General recommended dose of fertilisers for various crops grown in India

Crop name		NPK Recommendation (Kg/ha)		
		N	**P_2O_5**	**K_2O**
Cereals	Rice	120-150	40	20-40
	Wheat	120-150	60	40-60
	Barley	60-80	30	-
	Maize	80	40	20
	Sorghum	80-100	40-50	40-50
Oilseeds	Rapeseed and Mustard	120	30-50	20-40
	Groundnut	40-45	20-30	40
	Soybean	20-30	60	30-40
	Safflower	60	25-40	-
	Sunflower(Short duration)	30	40	30
	Sunflower(Long duration)	60	80	60
	Linseed	40	30-45	30-40
	Sesame	20-50	40	15-30
	Castor	45	60	-
Legumes	Pigeon pea	15-25	60-80	20
	Green gram	10-20	40-60	20
	Black gram	10-20	40-60	20
	Cowpea	20-30	40-60	40-60
	Horse gram	20	30	-
	Moth bean	10-20	40	-
	Chickpea	15-20	40-60	20
	Cluster bean	20	50	-
	Lentil	10-25	30-60	20
	Field pea	20-40	50	20

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	French bean	90-120	60	-
	Lathyrus	10	40	-
	Hybrid cotton	120-150	60-75	60-75
	Cotton (North India)	80-100	30-50	-
	Jute	60	30	30
Fibre crops	Mesta	60	30	30
	Sunhemp	20	40	40
	Sorghum (Two cuts)	60 (Basal) 50 (After cut)	60	60
	Pearl millet	50 (Basal) 30 (After 1month)	30	30
	Maise	80-100	40	-
	Teosinte	60 (Basal) 30 (After one month)	30	-
	Oats	120	40	-
Fodder crops	Guinea grass	60 (Basal) 40 (After each cut)	50	40
	Napier-Bajra Hybrid	60 (Basal) 30 (After each cut)	50	40
	Setaria grass	40 (Basal) 20 (After each cut)	40	40
	Para grass	40 (Basal) 40 (After each cut)	50	50
	Rice bean	20	50-60	-
	Berseem	20	80-90	30-40
	Lucerne	20	60-75	40
	Sugarcane (North India)	120-150	80	60
	Sugarcane (South India)	250-350	100	80
Cash crops	Potato	120	80	100-120

Courtesy: Prasad, 2002

2) *Use of Customised fertilisers*

Customised fertilisers are multi-nutrient carriers containing macro and micronutrients for satisfying the crop needs that are site-specific and validated by scientific crop model. It is the emerging concept based on the balanced nutrient fertilisation approach to address the crops' multiple nutrient needs. The customised fertilisers are manufactured by different macro and micronutrient combinations such as sulphur, zinc, and boron combined to the urea, DAP and potash in a proportion that will be able to fulfil the crop demand.

3) *Integrated nutrient management approach*

Neither application of chemical fertilisers alone nor the application of organic matter alone can meet all the crops' requirements. Crops do not only need significant nutrients (N, P and K) alone; they also require micronutrients and trace elements in smaller amounts. The

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intensive cultivation leads to a decline in the soil carbon status, resulting in a decline in the nutrient and water holding capacity of the soils. Hence it is required to manage all the nutrients in an adequate amount and enrichment of soil carbon. The addition of organic matter helps improve soil quality to sustain biological productivity, maintain environmental quality and promote plant and animal health. Hence, integrated nutrient management combines economic, efficient traditional and improved technologies from the symbiosis and synergy of crop-soil environment bio-interactions. Integrated nutrient management is the most logical way of managing long term soil fertility and productivity. Integrated use of organic manures, chemical fertilisers, crop rotations, and crop residue incorporation has been found promising in arresting the decline in productivity through increased fertiliser use efficiency and correcting marginal deficiencies of secondary and micronutrients and their beneficial influences on the physical and biological properties of the soil. Integrated nutrient management can bring about equilibrium between degenerative and restorative activities in the soil environment.

4) Soil test based fertiliser recommendation

In this approach, the soil is tested for different nutrients such as N, P, K and their status in the soil where the soil is categorised into low, medium and high fertility classes. The state-level fertiliser recommendations for a particular crop and variety are given from time to time in the package and practices of different seasonal crops, meant for medium soil fertility classes. If the soil tests result shows low fertility status for any particular nutrient, then the dose for that nutrient has to be increased by 25%, and if the soil tests result show high fertility for any nutrient, then the dose for that nutrient has to be decreased by 25%. With the recent Soil Health Card initiative by the Govt of India for the farmer's field, farmers are recommended optimum doses of fertilisers and manures to maintain good soil health.

5) Soil test crop response approach

Recommendation from this approach is specific to a given type of soil, crop and climatic situation. This contribution of soil available nutrient and yield level needs to be taken into account for recommending fertiliser dose for a particular crop. This approach is also known as prescription based fertiliser recommendation. Three essential parameters are worked out for the fertiliser recommendations:

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- $\boldsymbol{Nutrient\ requirement}\ \left(\frac{\boldsymbol{KG}}{\boldsymbol{q}}\right) = \frac{Uptake\ of\ nutrients\ \left(\frac{Kg}{ha}\right)}{Grain\ yield\ \left(\frac{q}{ha}\right)}$

- $\boldsymbol{Efficiency\ of\ soil\ available\ nutrients}\ (\boldsymbol{CS}\%) =$
  $\frac{Uptake\ in\ control\ plot\ \left(\frac{kg}{ha}\right)}{Soil\ test\ value\ of\ nutrient\ \left(\frac{kg}{ha}\right)\ in\ control\ plots}\ x\ 100$

- $\boldsymbol{Efficiency\ of\ fertilizer\ nutrient}\ (\boldsymbol{CF}\%) =$
  $\frac{Total\ uptake\ in\ fertilized\ plot - (STV\ in\ fertilized\ plot\ x\ CS)}{Nutrient\ applied\ through\ fertilizer}\ x100$

6) *Diagnosis and recommendation integration system*

In this approach, plant samples are analysed for nutrient content, and they are expressed as ratios of nutrients with others *viz;* N/P, N/K, P/K etc. Suitable ratios of nutrients are established for higher yields from experiments and plant samples collected from farmer's fields. The nutrients whose ratios are not optimum for high yields are supplemented by top dressing. This approach is generally suitable for long-duration crops, but it is tested for short duration crops like soybean, wheat, etcetera.

7) *Site-specific nutrient management (SSNM)*

The optimal and supplemental application of nutrients to meet the plants' temporal and spatial needs at a specific site is called site-specific nutrient management. It is an approach for need-based 'feeding' of nutrients to the crops. It allows optimum use of existing nutrients such as soil reserves, residues and manures. It ensures to management of soil nutrient variations throughout a field with prescription fertiliser application. This approach involves three steps:

Step 1: Establish an attainable yield target

Step 2: Effective utilisation of indigenous nutrients

Step 3: Apply fertiliser to fill the deficit between crop needs and indigenous supply

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SSNM strategies should be followed in the areas facing one or more problems such as areas having low yield levels due to unbalanced use of fertilisers, areas with heavy pest infestation on the crops due to overuse of N fertiliser or inefficient use of potash fertiliser, areas with the evidence of large mining of phosphorus and potassium and areas having deficiencies of secondary elements and micronutrients in crops and soils.

Conclusion

N: P: K use ratio is widening in India, and there is an immediate need to reduce the N: P: K use ratio to improve the country's crop productivity and agricultural sustainability. Imbalanced and inadequate use of fertilisers not only decreases the factor productivity but also threatening agricultural sustainability. There is a need to optimise the nutrient application in a more balanced way to maintain crop productivity and soil health. Balanced fertilisation is only a way to tackle the problem of nutrient mining from the soil. There are various ways to achieve a balanced fertilisation strategy such as recommended fertiliser dose application, customised fertilisers, proper utilisation of all the resources that can fulfil the crop's nutrient demand through integrated nutrient management approach, soil testing, and SSNM to find out the nutrient demand. The adoption of balanced nutrient fertilisation will significantly increase crop productivity and agricultural sustainability and help in ecological sustainability.

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