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Steps to reduce over-reliance on chemical fertilisers

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Low-grade rock phosphate can be used directly in acidic soil in Eastern India in kharif *season for rice and jute crops. Phosphate solubilising bacteria are suitable for P deficient soils, fungi for acidic degraded soil, while mycorrhiza is the right option for low moisture upland soils. Green manuring and green leaf manuring can easily substitute up to 50% of urea easily. Recycling crop residues and cow dung as compost and vermicompost help to replace 17% of chemical fertiliser consumption. In addition, crop diversification and biological N fixation can replace about 25% of urea use. Use of ash, fly ash, other industrial wastes, and potassium (K) solubilisers are some other options for reducing K fertilisers use. Use of alternate fertiliser materials, soil testing, suitable cultural practices, and artificial intelligence can also help in reducing the use of chemical fertilisers. This article provides a list of alternative solutions for synthetic chemical fertilisers to improve the food as well as soil quality.*

Keywords: Cultural practices, DAP, Green manure crops, Organic compost, Urea

INDIA has a target of becoming *Atmanirbhar Bharat* (Self-reliant India) by the year 2047. Presently, over-reliance on chemical fertilisers is one of the obstacles to achieve the target. It is a fact that introduction of chemical fertilisers, irrigation facilities, and fertiliser responsive high yielding varieties (HYVs) helped in achieving the Green Revolution. However, subsequent challenges accrued in terms of decline in soil fertility, reduced fertiliser use efficiency, and adverse effects on environment such as water pollution, soil pollution, and greenhouse gas emission. One of the causes behind such problems include indiscriminate and imbalanced fertiliser application targeted for an increased intensification of cereal crops, mainly rice, wheat and maize. These crops respond to high application of N. Over the time, the application of nitrogen fertiliser has increased in an attempt to increase the production, leading to imbalanced nutrient content in soil as well as plants. In 2024–25, N, P_2O_5 and K_2O fertiliser consumption in total has reached 32.93 million tonnes (mt) which is equivalent to 70.7 mt fertiliser products such as urea, Diammonium phosphate (DAP), muriate of potash (MOP), etc. The K_2O consumption was 10.74 mt and the remaining 22.09 mt consists of N + P_2O_5. Urea alone is accounted for 38.7 mt or 17.6 mt N equivalent. The N: P_2O_5: K_2O consumption ratio has increased over some years from 6.7:2.5:1 to 9.3:3.5:1. This means N consumption at present is 9.3 times more for every1 unit of K_2O and 3.5 units of P_2O_5. Ideally, the ratio should be 4:2:1. Thus, the fertiliser use pattern is increasingly being distorted with increased share of the N. The over-reliance on chemical fertiliser at present need to be reduced urgently by adopting suitable alternative practices.

Alternatives to reduce use of important chemical fertilisers

Diammonium phosphate (DAP):

Substituting with rock phosphate (rock-P): The results of All India Coordinated Agronomic Research Project encourages substituting DAP with the rock-P in moist acidic soils of eastern India (West Bengal, Bihar, Odisha, and North-Eastern states), especially during *kharif* season for rice and jute crops. Low-grade rock-P is a slow-release source in the presence of water and acidic soil (pH<5.5). This alternative option for moist acidic soils is highly effective, sustainable and cost-efficient with a reduced reliance on DAP.

Rock-phosphate can also be applied to the green manure crops. Green manure crops such as *Sesbania* for lowland rice and sunhemp for upland rice is recommended and also practiced to some extent in farmers' field. It is well proven that rock-P is transformed to available P due to acidic environment created by the roots of green manure crops and soil microbes in hot and moist soil of tropics. Green manure crops belonging to legume family consume more P and return the amount to soil in an easily decomposable form. Further, the organic acids released during decomposition of green manure helps in releasing P in available form from soil and applied rock-P. This can also reduce the DAP use significantly.

Use of P enriched compost/ vermicompost: Rock-P, other P bearing minerals, single super phosphate (SSP) and tri-super phosphate (TSP) should be mixed with organic materials during compost preparation. This results in rapid transformation of P to available form with the help of organic acids and microbial activity. This enriched compost possess high P use efficiency similar to DAP.

Alternative source of DAP in pulses, oilseeds, fruit and plantation crops: Pulses and oilseeds benefit from SSP and TSP due to co-supply of calcium (Ca) (up to 21%) and sulphur (S) (up to 12%). Such benefit is not feasible with DAP. Oil synthesis, protein formation, and nitrogen fixation is better when the source is SSP rather than DAP. Long duration fruit and plantation crops may be provided with alternative fertilisers like SSP, TSP, rock-P, bone meal, etc. in exchange of costly DAP as the former sources release P slowly over a prolonged period for the benefit of such crops.

Foliar spray of DAP or nano DAP in seasonal food legumes: Foliar spray needs little P application as compared to the soil application. Studies show that one kg of foliar-applied P can be as effective as 20 kg applied to soil. About 90% of applied foliar P is utilised by the plant. Therefore, the application quantity of DAP can be significantly reduced by foliar spray. This is suitable for legume crops with high P demand. Also, the short plant height of these crops facilitates easy spraying. Problematic soils such as saline and alkaline soil and in deficit soil moisture situations, foliar spray is the right option.

Phosphate solubilising microbes: Bacteria (*Bacillus megaterium*, *Pseudomonas fluorescens*, *Azospirillum brasilense*, *Enterobacter* spp.), fungi (*Aspergillus niger*, *Penicillium bilaii*, *Trichoderma harzianum*), and Arbuscular mycorrhizal fungi (*Rhizophagus intraradices*, *Glomus mosseae*) can save up to 25–30% of P fertilisers by solubilising soil-P and increasing yield by 20–25%. Bacteria are suitable for P deficient soils, fungi for acidic degraded soil, while mycorrhiza is the right option for low moisture upland soils. Phosphate solubilising microbes produce organic acids and phosphatase enzymes which can solubilise rock-P easily and release P in plant available form.

Recycling of industrial wastes: Fly ash is generated in huge quantity from thermal power plants. It varies in mineral nutrient contents with the coal source. However, in general, these ashes are rich in potassium, phosphorus, Ca magnesium (Mg) and silicon (Si). Use of fly ash as part of integrated plant nutrition system can reduce the reliance on imported P and K fertilisers. Bones, hooves and other wastes from the meat and fish processing industry provide P-rich organic fertiliser. Phosphogypsum, waste from phosphate fertiliser plants, contains phosphorus (0.5–3% P_2O_5) and can be used as source of P. Sewage sludge incinerator ash is a source for P (up to 20% P_2O_5) and K. Rice husk ash, a by-product of rice mills, also contains up to 1.2 % P_2O_5 and K up to 5% K_2O. Similarly, press mud or gypsum can be used along with rock-P to enhance P availability in paddy soil.

Urea:

Green manuring and green leaf manuring: Leguminous green manure crops such as *Sesbania* in medium and lowlands while sun hemp, cowpea, and milk vetch, etc. in uplands are ideal green manure crops before rice crop. These crops can fix about 50 kg N/ha. This practice helps to meet about 50% of urea used in transplanted rice. Similarly, in direct seeded upland and lowland rice, wheat and maize crops, 25% of urea use can be saved easily by intercropping of these food crops with suitable green manure crops. Loppings of twigs and leaves from *Gliricidia sepium* (*Jindabali*), *Pongamia glabra* (*karanj*), *Azadirachta indica* (Neem), *Leucaena leucocephala* (*Subabul*), etc. can be used for green leaf manuring and save up to 50% of urea need. *Sesbania* can be grown in saline and alkaline soils and lowlands and waterlogged areas, however, the early seedling stage must be aerobic soil for good growth of *Sesbania* and nodulation. Most upland green manure crops prefer light to medium textured soils.

One-month old *Sesbania* for green manuring in transplanted rice

Residue recycling as compost/ vermicompost: Wheat straw, rice straw, weed biomass, green manure biomass, hedge clippings, cow dung, other agricultural residues and bagasse, etc. can be recycled into vermicompost, and compost. Vermicomposting is faster (60–90 days) than traditional composting and nutritionally superior. It has potential to convert 173 tonnes of crop residues and 35.7 tonnes of cattle dung into ready-to-use manure. It has potential to save 17% of chemical fertiliser consumption (5.68 tonnes). This helps in improvement in soil

Vermicompost production using portable beds structure, cation exchange capacity, microbial activity, and water holding capacity which is indirectly useful to reduced fertiliser use by promoting root growth, reducing pest pressure and beneficial hormonal effect. On-farm studies revealed that 50% of fertiliser need can be substituted by residue recycling as vermicompost and compost.

Crop diversification: Nitrogen-recycling farming lays emphasis on legume crops in rotation. These crops need little N as a starter dose that can be fulfilled through organic source. With proper nodulation, N need of the crop is met from biological N fixation. Horse gram, moth bean, green gram, black gram, red gram, faba bean, chickpea and cowpea, etc. improve soil fertility and enhance nutrient cycling. The nodules present in the roots of the legume crops contains nitrogen fixing bacteria. Therefore, the roots are incorporated in the field for nitrogen recycling. In addition, the shallow fibrous root of cereals and deep tap root system of legumes interact for efficient use of water and nutrient in surface and sub-surface soil. Cereal-legume intercropping/rotation/mixed cropping is beneficial in reducing the need of N use. It is important to note that in presence of high fertiliser N, the rate of biological fixation is suppressed. Further, balanced use of potassium is promoted due to affinity of fibrous roots for K^+ while dicot roots have affinity for Ca^{++}. Thus, rice fallows can be utilised for legume crops to reduce the urea and MOP needs besides increasing pulses production in the country.

Biological nitrogen fixation: Symbiotic N fixers (*Rhizobium* and *Bradyrhizobium*) have most potential and can fix around 50–150 kg N/ha and reduce chemical fertiliser need by 25–30%. This helps to increase pulse yield by 20–25% and enhance the protein content in seeds. Associative N fixers (*Azospirillum brasilense*) in association with Poaceae roots can fix 20–40 kg N/ha by promoting root proliferation, and reduce fertiliser need by 15–20%. It can increase cereal yield by 15–20%. Free-living fixers (*Azotobacter chroococcum, Clostridium* spp.) can fix 10–20 kg N/ha and are useful in abiotic stress situations related to salinity and deficit moisture. In paddy system, Cyanobacterial biofertilisers (Anabaena, Nostoc) can fix 10–40 kg N/ha, reduce 25–30% N dose and increase rice yield by 10–20%. This biological N fixation system works well in situations of low chemical fertiliser use and has assume importance in future for a self-reliance system.


Training on *Rhizobium* inoculation in green gram seed

***Muriate of potash*:**

Residue recycling: Cereals with fibrous root system scavenge the monovalent soil potassium (K) efficiently. Rice–wheat system deplete soil K very fast. About 50% of K use can be reduced by in-situ recycling of straw and stover. The K content in plant residue is not bound to any biochemical compound and can be easily leached out to the environment when come in contact with water. So, *in-situ* residue recycling and capture by roots of green manure crops and weeds, and subsequent use by transplanted rice crop is useful.


Azotobacter inoculation in paddy seeds

Use of ash, fly ash and other industrial wastes: The use of fly ash, wood ash, and other industrial wastes such as cement kiln dust and sugar beet lime can be used to reduce K fertiliser use. Fly ash typically contains 0.24–3.6% K_2O besides Ca, Mg, S, and Si, and can reduce K fertiliser demand in integrated nutrient systems. Wood and biomass ash are highly alkaline and exceptionally rich in potassium up to 30% K_2O.

Use of K solubilisers: Potassium solubilising bacteria (*Bacillus mucilaginosus*) and fungi (*Aspergillus niger*) can mobilise available soil K. Application of P and K solubilising microbes in association can reduce P and K fertiliser use by 20–30%.

Common practices in reducing fertiliser usage

***Soil testing*:** Conducting regular soil tests prevents over-application nutrients. This is very important for P with high residual value (up to 70%) from previous season application and high spatial variability from 100–2,000 ppm in total P status. This is also true for K with 30% residual nutrient and high spatial variability (15,000–24,000 ppm in total K content). The K content in soil varies with the soil type. Vertisols (black soils) and alluvial soils generally have high exchangeable and reserved K. Laterite and red soils are often low in K due to leaching loss. Intensive cereal-cereal cropping system often result in K mining.

Regarding P content, vertisols are rich while lateritic soils, inceptisols and entisols are deficient.

Placement strategy**:** Phosphorus is relatively immobile in soil. Instead of broadcasting, applying P fertilisers close to the root zone (5 cm away and below the seed zone) improves use efficiency and reduces waste. This can reduce P fertiliser application by 20–30%. In case of transplanted rice, placement of basal dose of 50% N in reduced zone by incorporation during last puddling in clayey soil followed by partial incorporation of 25% N at tillering stage (20 days after transplanting) and maintenance of shallow submergence for a reduced soil condition favours high N use efficiency and saving of 20 kg N/ha. Another method of placing a urea super granule at the centre of each 4 hills can reduce fertiliser dose from 80 kg/ha to 56 kg/ha. It is labour-intensive, however, it can be feasible in small scale for marginal farmers with surplus family labour. Also, the soil type and water management must allow a soft mud for manual placement of super granules.

Split application**:** Rather than a single heavy application, split doses of N and also K improve the fertiliser use efficiency, offering the scope for reducing fertiliser dose. This is especially true for sandy soil and lateritic soil with high leaching and percolation rate. The number of split for N can increase from 3 in normal soil to at least 5 in problem soil while for K, it may be 2–3 splits from the present practice of no split to one split.

Extension of knowledge and use of AI**:** Enriching the available knowledge into the AI platform 'Bharat VISTAAR' will help in enriching information and generating location specific doable practices for reducing fertiliser use.

Low fertiliser requiring crops and varieties**:** Earlier the target was to produce more yield by developing and using fertiliser responsive varieties of food grain crops. But options also exist to grow high yielding varieties using moderate levels of N applications. Many lowland rice varieties need little N (20–40 kg N/ha), P (4 kg/ha) and K (8 kg/ha). Rasi, Vandana, Kalinga III, CR Dhan 40, Binadhan-17, BRRI dhan71, and BRRI dhan79 are some rice varieties tolerant to low soil P. Area under fertiliser intensive *rabi* maize may be reduced ignoring the high yield and return. The high yield and net return of this crop is possible due to use of high fertiliser dose, available at subsidized rate. Such profit is not possible if actual production price of fertiliser is considered. Similarly, in *Basmati* rice, fertiliser use may be more due to high price of the product in international market, and low price of fertiliser due to subsidy. It is important to note that the most profitable rate of fertiliser application need to be decided based on production cost of fertilisers, not the subsidised price.

Other cultural practices**:** Optimum time of sowing, water management, pest management and crop management also helps in the judicious use of fertilisers.

SUMMARY

There is an urgent need to reduce the over dependence on chemical fertilisers for agricultural production. Use of indigenous minerals, industrial by-products, organics, and potential soil microbes are good alternative options. The rate of fertilisers application can be revised based on the soil testing. Varieties yielding optimally with moderate dose of fertilisers can be made a new criterion for varietal selection besides following the other cultural practices. With the help of available alternatives, scientists' knowledge and artificial intelligence, location-specific and seasonal advisory can be generated in practicing lesser application of chemical fertilisers and to improve both soil and food quality.

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