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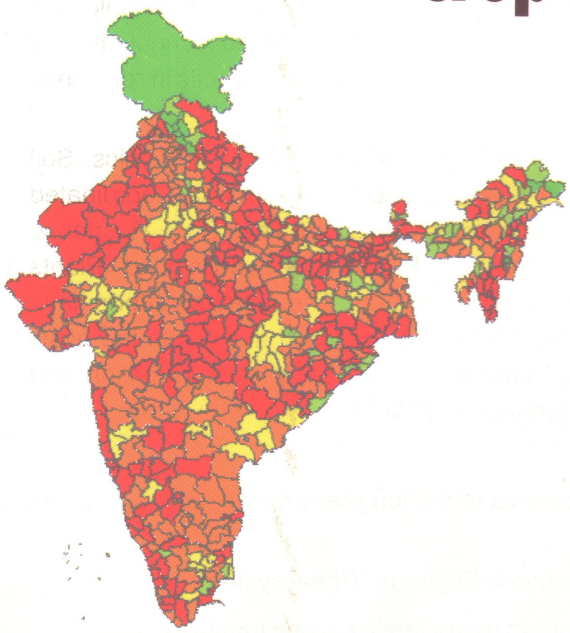
Agrisearch with a human touch

Farmer Friendly Technological Options for Sustainable Soil Health and Enhanced Crop Production



Farmyard Manure Availability
(Tonnes/ha of Net Cropped Area)

Farmyard Manure (t/ha)

- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 – 3.5
- 3.5 – 7.0
- 7.0 – 17.0

Institute Technology Management Unit (ITMU)
Indian Institute of Soil Science
Nabibagh, Bhopal – 462 038 (M. P.)

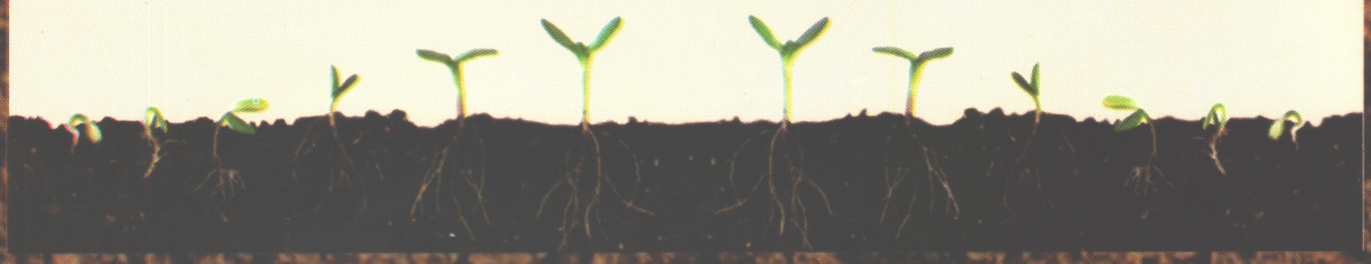
Indian Institute of Soil Science

Indian Institute of Soil Science (IISS) was established by the Indian Council of Agricultural Research (ICAR) in the year 1988 at Bhopal. The mandate of the institute is to *provide scientific basis for enhancing and sustaining productivity of soil resources with minimal environmental degradation* and prime objectives of the institute consist of "basic and strategic research on soils especially physical, chemical and biological processes related to management of nutrients, water and energy; development of advanced technologies for sustainable input management; and development of database repository of information on soils in relation to quality and productivity".

The research activities of the institute are being carried out under four divisions viz., Soil Physics, Soil Chemistry and Fertility, Soil Biology, and Environmental Soil Science; and three All India Coordinated Research Projects (AICRPs) on Long Term Fertilizer Experiments (LTFE), Soil Test Crop Response Correlation (STCR), Micro & Secondary Nutrients and Pollutant Elements in Soils and Plants (Micronutrients), and one Network Project on Soil Biodiversity and Biofertilizers. The research efforts have produced some effective technologies for enhancing soil heath and crop production along with the basic information on soil processes, nutrient dynamics and input management. Some basic information and technologies generated by the institute in the last 25 years are grouped as follows

Basic Information

* Understanding soil chemical, physical, and biological processes under long-term cropping, manure and fertilizer use.
* Quantification of N_2 fixation and N benefit from biological fixation in Soybean-Wheat system.
* Mineralization kinetics and transformations of S under long-term use of fertilizers and manures.
* Determination of soil potassium stocks in Indian semi-arid tropics in terms of biotite content.
* Zinc dynamics in major benchmark soils of India.
* Impact of long term tillage, residue, water & fertilizer management on soil health and crop productivity.
* Carbon sequestration under low, medium, and high management systems in different regions.
* Soil and produce quality under organic farming.
* Quality standards for urban solid waste composts.
* Maturity indices for composts.
* Sink capacity of soils for metal pollutants.
* Impact of polluted irrigation water in Ratlam - Nagda industrial area and remedial measures.
* Mobilization/utilization of P from low-grade rock phosphate using soybean leaf litter.
* Soil test maintenance P requirement of Soybean-Wheat system.
* Climate change and soil organic carbon dynamics.
* Assessing soil biological quality under Integrated Nutrient Management (INM).
* Development of malachite green method for the quantification of P in various soil extracts.

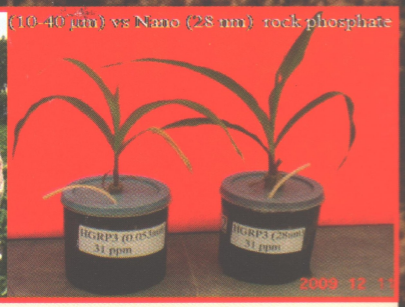


Technologies to Enhance Soil Fertility through Input / Nutrient Management

1. **Integrated Plant Nutrient Supply (IPNS) System for Soybean-Wheat Cropping System:** The general fertilizer recommendation for Soybean is 20:60:20 kg NPK/ha and that of Wheat is 120:60:40 kg NPK/ha to gain a profitable yield from the Soybean-Wheat cropping system. Realizing the low soil fertility status of the Malwa and Vindhyan plateau regions of Madhya Pradesh where the Soybean-Wheat cropping system is being practiced, the Institute has developed specific IPNS recommendation to make the cropping system more profitable. The recommendation consists of the application of 50% recommended rate of NPKS (Urea 1.75 kg, DAP 65 kg, MOP 16.5 kg, and Gypsum 55 kg/ha) + 5t FYM/ha + *Rhizobium* (750 g/ha) to soybean and 75% of recommended rate of NPKS (Urea 158 kg, DAP 98 kg, MOP 25 kg, and Gypsum 83 kg/ha) + Phosphate Solubilizing Bacteria (PSB) (3.5 kg/ha) to Wheat. The technology is found viable since many of the farmers can produce 5t FYM per annum. But, for some farmers it may not be possible to cover the entire holdings with complete INM every year as the FYM available may not be sufficient. These farmers can go for 100% NPKSZn to soybean and 100% NPKS to wheat to those parts of their fields where FYM is not applied, to get higher productivity in the Soybean-Wheat system *(Bulletin No. 4, 2003, IISS, Bhopal).*
2. **Soybean based Intercropping Systems for Sustainable Productivity on Deep Vertisols of Madhya Pradesh:** Intercropping systems are sustainable as these lower runoff and soil losses compared to sole crops. Field trials conducted at IISS conveyed that *Kharif* intercropping of Soybean with Maize (2:1 ratio) without any nitrogen application but with 5 t/ha FYM; followed by Wheat in *Rabi* is found to be more productive and economical with a benefit-cost ratio of 2.37 compared to the mono-cropped Soybean – Wheat System. However, the application of 100% NPK in maize-wheat system will give the highest profitability. Farmers could consider intercropping where soils are susceptible to erosion.
3. **Mechanical Harvest Borne Wheat Residue Management:** The field burning of crop residues is a wasteful practice as it results in loss of valuable organic matter, and associated nutrients. An experiment conducted for five years has established that soil incorporation of wheat residue plus N supplementation through FYM at the rate of 28 kg N ha^{-1} (approx. 4 t FYM ha^{-1}) along with 30 kg P ha^{-1} for rainfed soybean and 68 kg N + 30 kg P ha^{-1} for irrigated (1+ 2 irrigations) wheat was more effective and profitable. Wheat residue incorporation resulted in 20–22% higher yields in soybean and 15-25% higher yields in wheat as compared to residue burning *(IISS Publication: Two Decades of Soil Research, 2009).*
4. **Micro and Secondary Nutrients Recommendation for Indian Soils :** A systematic procedure to diagnose and correct the micro and secondary nutrient deficiencies of Indian soils has been developed by the Institute through its AICRP on micro and secondary nutrients. A micro and secondary nutrients recommendation chart for the application of various micro and secondary nutrients for different crops and cropping systems has been developed *(Research Bulletin No.1/2012, IISS, Bhopal).*
5. **Enriched Compost Production:** Enriched composting is the process where the ordinary compost is fortified with the necessary plant nutrients so that it becomes more or less complete food for the plant. Different types of enriched composts developed by the institute are:

a. **Phospho Compost:** The technology has been developed using phosphate solubilizing microorganisms (*Aspergillus awamori*, *Pseudomonas striata* and *Bacillus megaterium)* phosphate rock, pyrite and bio-solids to increase the manurial value compared to ordinary FYM and compost. The average P content of this compost is 2.0-3.5 % and the cost incurred to obtain one kg P_2O_5 through phosphocompost was around Rs.9 as compared to Rs.16-17 supplied through single super phosphate or Diammonium phosphate *(Technical Bulletin (Hindi), Nov. 2000).*

b. **Phospho-Sulpho-Nitro Compost:** In this composting process urea @ 0.5-1% (w/w), rock phosphate @12.5% (w/w) and pyrite @ 10% (w/w) are added into the composting mixture. The average nutrient value of this compost is 1.5-2.3% N and 3.2-4.2% P. Application of phospho-sulpho-nitro compost @ 5 t/ha can replace 25% of recommended fertilizer dose in Soybean-Wheat Cropping system *(Technical Bulletin No.2/2006, IISS, Bhopal).*



c. **Spent Wash amended Compost:** This compost is prepared by heap method but water requirement for the composting is met by spent wash, the major waste material from the distillery industry. Spent wash is rich in organic matter content and a good source of plant nutrients like N, P, K, S etc. After preparation, the nutrient value of spent wash amended compost is 1.37% N, 1.30% P and 1.82% K. The field demonstrations showed that the yield increase by the application of spent wash amended compost is almost equal to that of two other treatments (FYM, Ordinary Compost) in maize. In chickpea the yield increase was on par with the application of recommended dose of NPKSZn, and that of FYM + 50% of NS top dressing *(IISS Research Bulletin No. 2, 2012).*

d. **Enriched Organo - Mineral Compost:** In this method of composting, crop residues are mixed with cow dung, low-grade rock phosphate, waste mica and mineral gypsum and the composting period is nearly four months. The nutrient value of enriched organo-mineral compost is 1% N, 1% P, 2.1% K, 1.7% S and the addition of 1 tonne compost can supply 10 kg N, 10 kg P, 21 kg K, and 17 kg S to the crop. Field demonstrations conducted by the Institute proved that yield performance of organo-mineral compost is promising when used as a part of Integrated Nutrient Management (INM) *(ACIAR Project Technical Paper (Folder): Phosphorus, Potassium & Sulphur enriched Organo-Mineral Compost Production Technology, IISS, Bhopal).*

e. **Microbial enriched Municipal Solid Waste (MSW) Compost:** The Institute has developed microbial enriched compost technology to make use of the untapped nutrient value of the municipal solid waste as well as to manage the environmental pollution issues related to that. For making 1000 kg microbial enriched compost, 1600 kg waste material, 320 kg fresh cow dung and 21 kg Urea are required. To enhance the decomposition process bioinoculum need to be added twice during the composting period; initially in the first five days and then after 30 days of decomposition. The composting period for this method is around 2.5 months and the nutrient value of microbial enriched MSW compost is 0.73% N, 0.79% K with 11.3% total organic carbon content *(Institute Publication (Folder): Microbial Enriched Compost Production from Municipal Solis Waste, IISS, Bhopal).*

6. **Biofertilizers:** Biofertilizers are preparations of living organisms that are useful for promoting plant growth through a variety of mechanisms like biological nitrogen fixation, solubilization of insoluble phosphates, oxidation of sulphur, production of growth hormones, and also help plants to fight against diseases *(Research Progress Report: Network Project on Soil Biodiversity-Biofertilizers (2007-2011) IISS, Bhopal).*

a. **Mixed Consortium Biofertilizers :** Mixed biofertilizers (BIOMIX) containing a consortium of N fixers, P solubilizers and Plant Growth Promoting Rhizhobacteria (PGPR) to promote crop growth of cereals, legumes and oilseeds was developed through the Network Project on Soil Biodiversity and Biofertilizers. Field trials conducted at various centers of the Network Project showed that use of BIOMIX could save 25% of N and P fertilizers. Field trials of BIOMIX in various states showed an yield increase of 13% in rice, 9% in wheat, 10% in millets, 13% in pulses, 14% in oil yielding crops, and 10% in vegetables.

b. **Enhancement of Biofertilizer Efficacy**: Bioinoculants (*Azospirillum, Azotobacter,* PSB) mixed with well decomposed FYM/Vermicompost in 1:25 ratio and incubated at 30% moisture for a week improved the microbial population 2-15 fold. Demonstrations revealed an yield increase of 8-12% in above ground vegetables and 25-30% in below ground vegetables with the use of this formulation.

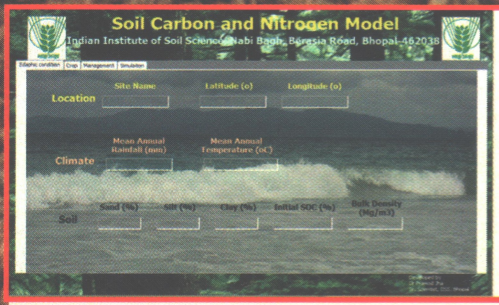
c. **Liquid Biofertilizer Formulations:** This technology is developed by ANGRAU, Amaravathi center of Network Project on Biofertilizers. Liquid biofertilizer formulations found to be ideal to increase the shelf life of different biofertilizers. In an evaluation period of 360 days Liquid *Rhizobium* medium maintained log 8.433 viable cells/ml, Liquid PSB medium maintained log 8.208 cells, and *Azospirillum* liquid medium maintained log 8.643 CFU (Colony Forming Uints)/ml even after 360 days. Liquid inoculants found to be free of contamination during the study period and dose of 4-5 ml of liquid inoculum (population of $3x10^9$ cells/ml) is enough to coat 1 kg seed.

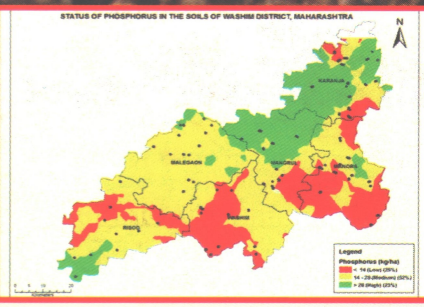
7. **Oleoresin Coated Urea Fortified with Nano-particles:** To mange the micro-nutrient requirement of the crop a protocol has been developed for the fortification of urea with a consortium of nano-particles of Zinc, Copper, Iron, and Silicon by using oleoresin. This product contains 0.438g N, and 2.2 mg Zn, 1.10 mg Fe, 0.66 mg Cu and 1.06 mg Si per gram of urea. Application of this fortified urea @ 200 kg/ha will supply 87.68 kg N, 440 g Zn, 220 g Fe, 132 g Cu, and 212 g Si to the crops.

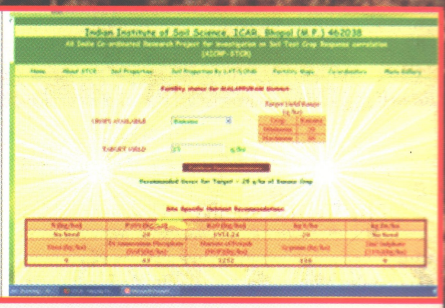
8. **Nano-Rock Phosphate:** Development of Nano Rock Phosphate is an effort towards the commercial utilization of the low grade rock phosphate available in India as a direct phosphatic fertilizer. Experiments conducted in four soils (Vertisols of Bhopal, Alfisols of Betul, Inceptisols of Ludhiana, and Aridisols of Jodhpur) revealed that crop utilization of P from nano-rock phosphate is on par with that of normal sized SSP in Vertisols and Inceptisols; and biomass growth of maize could be enhanced with the application of nano-rock phosphate. The institute has tested two types of rock phosphate materials SRP (Sagar Rock Phosphate) and HGRP (High Grade Rock Phosphate, Udaipur) and found that nano-rock phosphate (size:110.1 nm) prepared from SRP had showed an yield advantage of 20% in vertisols, 61% in alfisols, 31% in inceptisols, and 14% in aridisols over the application of normal sized rock phosphate (size:13.4 µm) from SRP. Further, nano-rock phosphate (size:70.89 nm) prepared from HGRP had showed an yield advantage of 31% in vertisols, 88% in alfisols, 27% in inceptisols, and 15% in aridisols over the application of normal sized rock phosphate (size:12.9 µm from HGRP *(Adapted from IISS Technical Bulletin, 2010).*
9. **Nano Zinc Oxide:** Results of the experiments conducted at IISS revealed that Nano ZnO can be used as a direct source of Zn to crops. Application of nano Zn particles at relatively lower level (0.28ppm) enhanced the growth of maize compared to normal $ZnSO_4$ (0.5ppm); further, seed treatment with nano-ZnO @ 50 mg Zn/g seed found to be a successful method to meet the Zn requirement of the crop and there was no toxic effect on the seed germination and further plant growth *(IISS Technical Bulletin, 2010).*

Technologies to Enhance and Sustain Soil Health

1. **Conservation Tillage for Soybean-Wheat Cropping System:** Conservation tillage means any tillage system that maintains at least 30% of the soil surface covered by residue after planting primarily to reduce water erosion. The institute has tested different conservation tillage practices (No Tillage and Reduced Tillage) for soybean-wheat system. In no tillage system during the *kharif* season soybean crop was sown directly with a no-till seed drill while wheat residues were kept on the surface. Under reduced tillage system soybean was sown using a no-till seed drill in wheat residue retained field after one pass ploughing by duck foot sweep cultivator. An increase in soil water retention and soil properties were observed in both systems compared to that of field with conventional tillage but yield advantage was visible in the soybean crop grown in the reduced tillage system. *(IISS Publication: Two Decades of Soil Research, 2009)*
2. **Broad Bed Furrow (BBF):** The BBF system consists of semi-permanent broad beds of approximately 100 cm wide, separated by furrows of about 50 cm wide and 15 cm deep with a rolling slope of 0.4-0.7% for safe drainage of excess water; crops can be grown on the beds in 2-4 rows in this system. The system is a good option for cultivating crops in waterlogged areas; beneficial for high productivity, improved drainage, and also for in-situ moisture conservation. During heavy rainfall the furrows safely carry runoff water away without any excess soil loss and can drain the excess water to the water harvesting pond so that it can be used for irrigating the winter crop. On BBF, sole maize or intercropping of pigeon pea with maize crop (rainy season), chickpea (winter season) can be grown with application of recommended doses of fertilizer and FYM @ 5 t/ha. There was an yield increase of 11-18% in BBF system compared to that of flat bed system in the field demonstration among five cropping systems viz., soybean-chickpea, maize-chickpea, soybean/maize-chickpea, soybean/pigeonpea, and maize/pigeonpea; maize-chickpea system benefitted most by the BBF technology. *(IISS Publication: Two Decades of Soil Research, 2009)*
3. **Organic Farming Practices for Various Crops and Cropping Systems:** Organic farming is becoming famous for its nature friendly technology package comprising crop rotations, green manuring, compost use and biological control of pests and diseases. The institute has developed specific package of practices for organic farming for crops like soybean, wheat, isabgol, chickpea, pomegranate, mustard, and pigeonpea. *(IISS Publications: Folders for Soybean, Isabgol, Pigeonpea, Wheat, Chickpea, Mustard, and Pomegranate, 2012; Extension Bulletin 1/2006)*
4. **Bioremediation of Heavy Metal Contaminated Sites:** Bioremediation is an emerging technology that use microorganism/living plants to reduce and/or remove pollutants or contaminants from soil, water, sediments, and air. Phytoremediation is a tool of bioremediation where the green plants are used in situ for cleaning the contaminated sites. The institute has screened and identified some floriculture plants like marigold, chrysanthemum, gladiolus, tuberose and bio-agents like *Trichoderma viridie* for the management of heavy metal contaminated areas.







Database, Maps, and Software to Support the Management of Soil Health

1. **GIS based Soil Fertility Maps of Different States:** The soil fertility data on N, P, and K index values at district level for the states of Andhra Pradesh, Maharashtra, Chhattisgarh, West Bengal, Haryana, Orissa, HP, Karnataka, Punjab, and Tamil Nadu has been developed in MS-Access. From the attribute database, the different thematic layers were reclassified to generate various thematic maps on N, P and K index values (IVs). The calculated soil test values were incorporated into the developed fertility maps to prescribe nutrients for targeted yields. *(Institute Publication: Farmers' Resource Based Site Specific Integrated Nutrient Management and On-line Fertilizer Recommendations Using GPS and GIS Tools, 2010)*
2. **Online Fertilization Recommendation System:** This application software was developed to recommend fertilizer doses for the targeted yields of various crops. This system has the facility to input actual soil test values at the farmers' fields to obtain optimum fertilizer doses for nitrogen, phosphorus, and potassium. The application is a user-friendly tool. It will aid the farmer in improving the efficiency (appropriate dose) of fertilizer use to achieve a specific crop yield. The system works as a ready reckonner to give prescription in the form of fertilizers (eg. Urea, SSP, MOP etc. The software can be accessed at *http://www.iiss.nic.in*. The software is compatible with Internet Explorer. On entering the site one has to click "Run the software" shown in bold green colour. Please enable pop ups before clicking. After that one has to feed the information as directed *(Technology Bulletin No. IISS/GIS/01, 2007).*
3. **Database of Different Sources of Plant Nutrients:** The database has been generated in MS access. This database can be accessed by user friendly queries. To access the data one has to open the file Nutrientdatabase.mdb and then click queries. The user will find several queries which when clicked will ask the name of state, district, crop, manure type for which the information is desired. When user feeds the desired name, he will get the nutrient data. *(Research achievement : IISS Annual Report 2010-2011).*
4. **Soil Carbon and Nitrogen Turnover Model:** A new soil carbon and nitrogen turnover model has been developed by using the soil and crop dataset of long term fertilizer experiments of India. Soil carbon and nitrogen prediction model is controlled primarily by net primary production (yield), mean annual rainfall and temperature, texture (sand, silt, clay content), bulk density and soil initial carbon content. The model simulates soil carbon dynamics for different annual crops and plant communities. The model works on the principle of soil carbon saturation theory, which suggests soil carbon sequestration rate decreases as the soil carbon content increases and vice-versa. The model computes total organic carbon, Walkley & Black C content, carbon in resistant (passive) and mineralizable (active+slow) pools, carbon stocks, total N, and available N. Soil carbon and nitrogen prediction model uses a yearly time step and the users have to define only initial soil carbon content. The model itself determines the relative allocation of carbon in different pools. The model automatically computes the carbon and nitrogen turnover based upon these parameters and output is displayed in excel sheet.
5. **Software for Evaluating Municipal Solid Waste (MSW) Compost:** Municipal Solid Wastes have considerable potential to contaminate the environment but recycling of this waste material through composting can generate valuable resources for augmenting crop productivity. IISS has developed a new method that enable the grading of MSW compost based on its quality. This grading can be done for Marketable class on a four point scale or for Restricted Use class on a three point scale based on the *Fertilizing Index* and *Clean Index* of the MSW compost. The Fertilizing Index is calculated with the weighing factors assigned to the compost quality parameters while Clean Index is calculated based on the weighing factor assigned to different heavy metals as well as their content in the prepared compost. The software developed with this method is available in the institute in a CD format *(Institute publication: Grading of Municipal Solis Waste Compost for Safe and Maximum Recycling in Agriculture).*

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