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# Indian Farming

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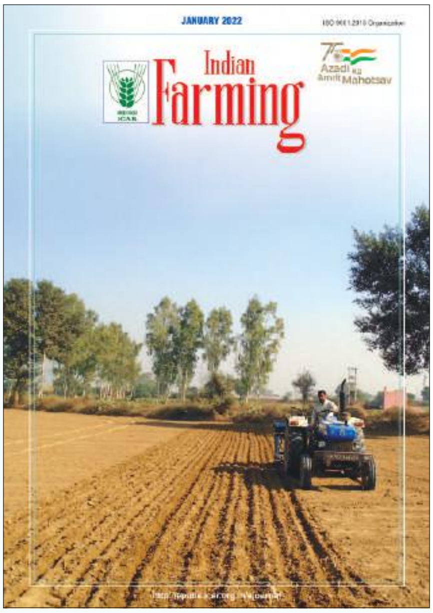


**Cover I :** Field preparation for sowing of wheat crop

**Cover IV :** United Nations Decade on Ecosystem Restoration 2021-2030.



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## In This Issue

# Aboard the Agri-flight

For the second successive year, Covid-19 pandemic is playing havoc for the world, India in particular. Indian agriculture has progressed tremendously on every front despite the pandemic. Thanks to the government policies, initiatives and untiring efforts of our scientists, farmers and other stakeholders. Share of gross value added by agriculture was estimated at ₹ 19.48 lakh crore in 2020, which is 17.8% compared to other sectors. In India, total food grain production was recorded at 296.65 million tonnes in 2020 which is 11.44 million tonnes more compared with 285.11 million tonnes in 2019. For the year 2022, the government has set a target for farmers to increase food grain production by 2% i.e. to 307.31 million tonnes. In 2021, production was recorded at 303.34 million against a target of 301 million tonnes.

India has the highest livestock population of about 535.78 million, which is around 31% of the world livestock population. Milk production in the country was 198 MT in 2020. India is the second highest producer of rice, wheat, sugarcane, cotton, groundnut, and fruits and vegetables in the world. The Indian food industry is assured for huge growth due to its enormous potential for value addition, specially within the food processing industry. Indian food and grocery market is sixth largest market in the world, with retail contributing 70% of sales. The Indian food processing industry has grabbed 32% of the country's total food market. In India, the processed food market is expected to grow to ₹ 3,41,352.5 crore by 2025 as compared to ₹ 1,931,288.7 crore in 2020. The organic food segment in India will grow at a CAGR of 10% between 2015–25 and is estimated to reach ₹ 75,000 crore by 2025 as against ₹ 2,700 crore in 2015. In 2019, Coca Cola launched 'Rani Float' fruit juices.

Two diagnostic kits developed by ICAR-IVRI and the Japanese Encephalitis IgM ELISA were launched in 2019. Investment of ₹ 8,500 crore has been declared for ethanol production in India. In 2021, APEDA signed an MoU with ICAR-CCRI, Nagpur, for increasing export of citrus and its value-added products. In 2021, the Prime Minister launched 35 crop varieties with special traits such as climate resilience and higher nutrient content. The government has initiated Digital Agriculture Mission for 2021–25 for agriculture projects based on new technologies such as artificial intelligence, block chain, remote sensing and GIS technology, drones, robots and others. The Krishi UDAN 2.0 scheme proposes assistance and incentive for movement of agri-produce by air transport. India looks forward to achieve the ambitious goal of doubling farmer's income by 2022.

Wish you a happy and prosperous new year 2022.

RVerma

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*Indian Farming* **72**(1): 02–05; January 2022

# Pusa Mangal (HI 8713)

## A durum wheat variety boosting economy and nutritional security of central zone wheat farmers

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*Pusa Mangal (HI 8713), a high yielding durum wheat variety was released in 2013 by CVRC for high fertility, irrigated, timely sown conditions of Central Zone, which is the largest durum wheat producing zone in India. HI 8713 recorded a mean yield of 52.3 q/ha and showed good levels of field resistance to stem and leaf rusts over 3 years of testing in national trials. Farmers cultivating HI 8713 in Madhya Pradesh and Uttar Pradesh got bumper yields, i.e. 80-90% increase compared to the check varieties. Pusa Mangal showed consistent higher yield in national wheat trials as check variety and had higher breeder seed indent in the recent past. It indicates the potential of Indian durum wheat for export, and providing economic and nutritional security to the wheat farmers of central zone. High yield potential and quality make HI 8713 (Pusa Mangal) the best choice for inclusion in the nutrifarm scheme and an excellent raw material for the upcoming semolina-based pasta industries, generating additional employment opportunities, boosting farm economy and nutritional security in the country.*

**Keywords:** Durum wheat, High yield, Quality pasta

AMONG the cultivated wheat species, durum/macaroni wheat (*Triticum durum* L.) is the second most important species locally known as *Kathia* wheat/Pasta wheat. In India, every year more than 2.5 million tonnes of durum wheat is produced from nearly 10-11% of the total wheat area. Durum is the hardest of all wheat varieties and is more adapted to hot and dry wheat growing zones of India i.e. peninsular and central zones. Durum kernels are amber coloured with yellow endosperm, which gives its end products a golden hue. Premium pasta products are produced from durum wheat because of its yellow endosperm along with high gluten strength and protein content. In India, durum wheat is preferred over bread wheat in making a number of traditional recipes like *daliya*, *bati*, *bafla*, *laddu*, *churma*, *sevaiyan*, *suji-halwa*, *suji-upma,* etc. The demand for durum wheat is increasing because of its suitability to make unique food products and increasing consumption of these food products with rapid urbanization. Durum wheat cultivation has several advantages to offer like saving irrigation water due to its high water-use efficiency, minimizing the risk of rust epidemics because of its diverse rust resistance, providing naturally biofortified health food due to its high protein and micronutrient content.

HI 8498 (Malav Shakthi) which was released in 1999, was the only popular durum wheat variety under irrigated, timely sown conditions in central zone. To enhance and diversify the durum wheat cultivation, there was an urgent need for new durum wheat varieties with high yield, disease resistance and quality. ICAR-Indian Agricultural Research Institute, Regional Station, Indore developed a durum wheat variety HI 8713 (Pusa Mangal) from an indigenous cross HD 4672/PDW 233. HI 8713 was evaluated for 3 years under All India Co-ordinated Wheat and Barley trials (AICW&BIP) from 2009-2012 for yield, quality and adaptability among 37 locations of central wheat growing zone of the country (Madhya Pradesh, Chhattisgarh, Gujarat, Kota and Udaipur divisions of Rajasthan and Jhansi division of Uttar Pradesh). Significantly higher yield, disease resistance, quality, adaptability and plasticty of HI 8713 to sowing conditions led to the release of Pusa Mangal by Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops (CVRC), Government of India for commercial cultivation under timely sown, irrigation conditions of central zone in 2013.

HI 8713 (Pusa Mangal) growing in field

## Performance of HI 8713 in AICWI&BIP trials

HI 8713 was tested for 3 years during *rabi* 2009-12 in 37 locations of central zone along with checks. HI 8713 recorded mean yield of 52.3 q/ha and showed superiority over checks by giving 4.8-5.7% higher yield over durum wheat checks: HI 8498 and MPO 1215; and 1.5-19.3% yield superiority over bread wheat checks: Lok-1, GW 322 and PBW 343 (Table 1). In agronomic trials conducted during *rabi* 2011-12, HI 8713 showed significantly superior performance over checks: MPO 1215, HI 1544, HI 8498, GW 322 and plasticity to variations in sowing conditions. HI 8713 recorded more ear heads/sqm and number of grains/ear head compared to checks, which provided wide adaptability to this genotype.

HI 8713 is showing consistent performance in AICW&BIP trials as national check in NIVT 4 and as zonal check for central zone in advance varietal trials (AVT) from *rabi* 2017-18 till now (Table 2). It is considered as zonal check in a timely sown AVT trial along with HI 8737, GW 322 and HI 1544. HI 8713 had shown consistent higher yield (57.9 q/ha) compared to other checks HI 8737 (56.4q/ha), GW 322 (54.0 q/ha) and HI 1544 (52.9 q/ha).

## Disease resistance and quality traits of HI 8713

HI 8713 recorded high degree of resistance against important diseases like stem and leaf rust, flag smut and leaf blight in comparison to checks during AICW&BIP trials. It showed resistance to durum virulent pathotypes of the leaf rust and stem rust indicating that the resistance spectrum is different from that of the checks. It showed high level of resistance to the African stem rust race '*Ug99*' and its variants during screening in Kenya. The recent rust disease data from central zone AICW&BIP trials show HI 8713 is still resistant to major diseases, indicating its durable resistance.

HI 8713 has high yellow pigment content (7.16 ppm), less gruel solid loss and high overall acceptability compared to the durum checks (Table 3). It showed parity with the check varieties in other desired quality traits like grain appearance, protein content, test weight, etc. indicating its suitability for pasta making. HI 8713 has high protein content (12%) along with essential micronutrients, viz. iron content (36 ppm), zinc content (34 ppm) and copper content (6 ppm) which makes it the best choice for inclusion in 'Nutrifarm scheme' of Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India which includes 25 districts in Madhya Pradesh. It can serve as a dual quality durum suitable both for excellent pasta preparations as well as

**Table 1.** Mean yield (q/ha) of HI 8713 in coordinated trials

| Year of Testing | No. of trials | HI 8713 | Durum checks | | Bread wheat checks | | | | CD |
|---|---|---|---|---|---|---|---|---|---|
| | | | HI 8498 | MPO 1215 | Lok-1 | GW 322 | HI 1544 | PBW 343 | |
| 2009-10 | 5 | 50.7 | 45.1 | - | - | - | - | 42.5 | 3.7 |
| 2010-11 | 17 | 51.5 | 48.9 | 50 | 47 | 50.9 | 51.3 | - | 1.5 |
| 2011-12 | 15 | 53.8 | 51.6 | 49.5 | - | 52.8 | 53.5 | - | 1.6 |

**Table 2.** Performance of HI 8713 as check in AICW&BIP trials

| Variety | 2017-18 | | 2018-19 | 2019-20 | 2020-21 | | Mean yield |
|---|---|---|---|---|---|---|---|
| | NIVT | AVT | NIVT | NIVT | NIVT | AVT | |
| HI 8713 | 48.5 | 50.7 | 66.6 | 60.7 | 67.6 | 53.4 | 57.9 |
| HI 8737 | 48.8 | 50.1 | 62.7 | 58.2 | 62.0 | - | 56.4 |
| HI 1544 | 53.0 | 52.6 | 47.6 | 58.1 | 53.3 | 52.8 | 52.9 |
| GW 322 | 55.2 | 52.6 | 44.5 | 58.8 | 59.5 | 53.4 | 54.0 |

**Table 3.** Important quality parameters of HI 8713

| Character | HI 8713 | Durum checks | |
|---|---|---|---|
| | | HI 8498 | MPO 1215 |
| Grain appearance | 6.2 | 6.9 | 7.1 |
| Protein content (%) | 11.7 | 12.5 | 12.4 |
| Yellow pigment (ppm) | 7.16 | 4.99 | 5.29 |
| Sedimentation value (ml) | 29 | 33 | 29 |
| Yellow berry incidence (%) | 9 | 6.2 | 10.6 |
| Test weight (kg/l) | 82.9 | 83.4 | 83.3 |
| Hardness index | 70 | 86 | 78 |
| Iron (ppm) | 35.5 | 28.9 | 32 |
| Zinc (ppm) | 33.6 | 27.9 | 30.7 |
| Copper (ppm) | 6.02 | 5.55 | 5.63 |
| Manganese (ppm) | 32.9 | 26.5 | 30.6 |
| Cooking time (min) | 10.5 | 10.4 | 10.35 |
| Gruel solid loss | 1.37 | 2.38 | 2.45 |
| Overall acceptability | 8.3 | 5.7 | 5.7 |

for chapati making or blending purposes.

### Success stories of farmers cultivating HI 8713 and demand for seed

HI 8713 was demonstrated in farmers' field during *rabi* 2012-13 to 2014-15 along with popular bread wheat variety Lok-1 in Indore, Ujjain and Dewas districts of Madhya Pradesh by ICAR-IARI, Regional Station, Indore. HI 8713 showed about 80-95% average increase in yield compared to Lok-1 during these years (Table 4). It yielded more than 70 q/ha in *rabi* 2013-14 in all the field demonstrations. Farmers had expressed complete satisfaction about this variety in terms of grain production and productivity compared to their local popular bread wheat variety Lok-1. The farmers had conveyed that HI 8713 had fetched a higher price than Lok-1 in the grain mandis, which in turn increased their profitability in terms of economic returns.

HI 8713 (Pusa Mangal) Grain

Ten FLDs were conducted by KVK, Sehore each year during *rabi* 2015-16 to 2018-19 where HI 8713 was sown in 4 ha area under the thrust area Soil Health Management, Crop management practices. Pusa Mangal yielded in the range of 52-60 q/ha compared to the old variety which yielded 44-50 q/ha (Table 5). Increase in yield was recorded in the range of 7.3-12.0% which led to cost:benefit ratio of 3.62.

A progressive farmer Shri Govind Meena from village Kothara Pipalya, Nasrullaganj, Sehore district had sown it in 0.4 ha during 2018-19. Under the supervision of ICAR-ATARI, Zone–IX, Jabalpur (MP) and CRDE-Krishi Vigyan Kendra, Sewania, District- Sehore (MP) HI 8713 was harvested and yield was recorded as 64.58 q/ha compared to local check (53.18 q/ha). The net income with HI 8713 cultivation was calculated as ₹ 97,253/ha and cost:benefit ratio was 3.74 compared to farmers practice (2.86).

Progressive farmer Shri Prabhu Dayal, resident of Village Khiriya, Lalitpur District of Bundelkhand Region of Uttar Pradesh had sown HI 8713, seed procured from Krishi Vigyan Kendra, Lalitpur during *rabi* season 2018-19. He had sown HI 8713 and local durum wheat variety in one acre area each, and HI 8713 yielded 20.8 q/acre. The grain HI 8713 fetched a higher price of ₹ 2,500/q and could earn a net benefit of ₹ 40,800/acre. During last 3 years i.e. from 2018-19 to 2020-21, he sowed HI 8713 in 20 acres leading to an enhancement in production from 20 q to 500 q and gross income from 0.5 lakh to 12.5 lakh. Now, Shri Prabhu Dayal intends to grow *Kathia* wheat on a larger scale. He is also planning to encourage other farmers to take up cultivation.

Demand for HI 8713 seed among the farmers is growing since its release. The DAC indented release of Pusa Mangal has never been less than 200 q from 2016-17 and it was in the top 10 DAC indented wheat varieties during *rabi* 2018-19. The indent of HI 8713 during 2016-17 (248.8 q), 2017-18 (288 q), 2018-19 (462.2 q), 2019-20 (202 q) and 2020-21 (270 q) indicates the demand for the seed of Pusa Mangal among farmers.

**Table 4.** FLD Demonstrations of HI 8713 in comparison to Lok-1

| Farmer | Area (ha) | | Yield (q/ha) | | Yield Increase | |
|---|---|---|---|---|---|---|
| | HI 8713 | LOK-1 | HI 8713 | LOK-1 | q/ha | % |
| | | | *Rabi 2012-13* | | | |
| Deepak Wakhla | 0.4 | 0.4 | 53 | 30 | 23 | 76.7 |
| Banne Singh Chouhan | 0.4 | 0.4 | 64 | 30 | 34 | 113.3 |
| | | | | | Average | 95.0 |
| | | | *Rabi 2013-14* | | | |
| Durgalal Sisodiya | 0.4 | 0.4 | 74 | 38 | 36 | 94.7\ |
| Surajmal Dhangaya | 0.4 | 0.4 | 74 | 40 | 34 | 85.0 |
| Ajit Singh patel | 0.4 | 0.4 | 71 | 40 | 31 | 77.5 |
| Babulal Patel | 0.4 | 0.4 | 73 | 40 | 33 | 82.5 |
| Jiwan Patel | 0.4 | 0.4 | 72 | 42 | 30 | 71.4 |
| | | | | | Average | 82.2 |
| | | | *Rabi 2014-15* | | | |
| Salim patel | 0.6 | 0.5 | 58 | 32 | 26 | 81.3 |
| Nasir patel | 1.4 | 1.0 | 62 | 34 | 28 | 82.4 |
| | | | | | Average | 82.0 |

**Table 5.** FLD Demonstrations of HI 8713 conducted by KVK Sehore

| Year | Area (ha) | Yield (q/ha) | | Yield Increase | | Net revenue | | Cost:Benefit Ratio | |
|---|---|---|---|---|---|---|---|---|---|
| | | HI 8713 | Old variety | q/ha | % | HI 8713 | Old variety | HI 8713 | Old Variety |
| 2015-16 | 4 | 55.65 | 43.58 | 12.0 | 27.7 | 40361 | 58238 | 2.62 | 3.31 |
| 2016-17 | 4 | 51.6 | 44.1 | 7.5 | 17.0 | 40511 | 52523 | 2.58 | 3.11 |
| 2017-18 | 4 | 52.33 | 45.05 | 7.3 | 16.2 | 79134 | 64837 | 2.57 | 3.11 |
| 2018-19 | 4 | 59.81 | 49.35 | 10.5 | 21.2 | 93573 | 73241 | 2.88 | 3.62 |

**Source:* Annual reports of KVK, Sehore, MP

### Export potential of Indian Durum wheat

Durum wheat has a special niche in the Indian wheat economy. Indian durum wheat is typically purchased by the private trade at a premium price, mainly for processing high value products and generating additional employment through durum based pasta industry. There is also a huge potential of earning foreign exchange through the export of quality grain and value-added products. The grain and nutritional quality of durum wheat varieties: HI 8663, HI 8713, HI 8737, HI 8759 and HI 8777, viz. grain protein content (>13%), high iron (>45 ppm), high zinc (>40 ppm), yellow pigment (>6 ppm) content is in comparison with Canadian and Australian durums, which makes Indian durum wheat highly potent for export. However, the availability of exportable durum is limited and due to the lack of gradation system for durum wheat, it gets mixed with bread wheat in local markets. Special grading system and strict policies by the government in the procurement of durum wheat and preparation of pasta products from durum wheat only can boost the Indian pasta manufacturing industries and durum wheat growers.

## SUMMARY

Durum wheat cultivation is found to be highly profitable in central India due to varieties having high yield potential, rust resistance and high tolerance to drought and heat, which ensure more production with less irrigation. Around 13% of increase in durum wheat area was found in Madhya Pradesh compared to the durum wheat area in the last 5 years. With the rising demand from milling industries in and around Madhya Pradesh, farmers are increasingly taking up the cultivation of durum wheat. HI 8713 is a durum wheat variety with high yield, wider adaptability, high yellow pigment (7.16 ppm), good levels of essential micronutrients, and excellent dual quality grain with high levels of resistance to stem and leaf rust. Quality traits, viz. high hectolitre weight, less gruel solid loss and good grain appearance make Pusa Mangal, a best choice for good quality pasta. The success stories of farmers growing HI 8713 in terms of net revenue, cost benefit ratio and demand for the seed ensure Pusa Mangal can offer economic and nutritional security for wheat farmers of Central zone.

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# Herbicide resistance in *Rumex dentatus*

## A threat to sustainable wheat production in north-western India

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*Herbicide resistance in weeds is becoming a major challenge in Indian agriculture which is an alarming signal for sustainable crop production. Earlier herbicide resistance was confined to* Phalaris minor *only in wheat crop but now there are some reports of resistance in* Rumex dentatus *to metsulfuron methyl in Haryana and Punjab. To confirm this, a study was conducted at Punjab Agricultural University, Ludhiana during 2018-19 and 2019-20. This study showed that resistance has evolved in* Rumex dentatus *against metsulfuron methyl in many rice-wheat growing regions of Haryana and Punjab. This first report of resistance from Punjab indicates the spread of resistance in* R. dentatus*. Therefore, an integrated approach is required to control this resistance problem in* R. dentatus.

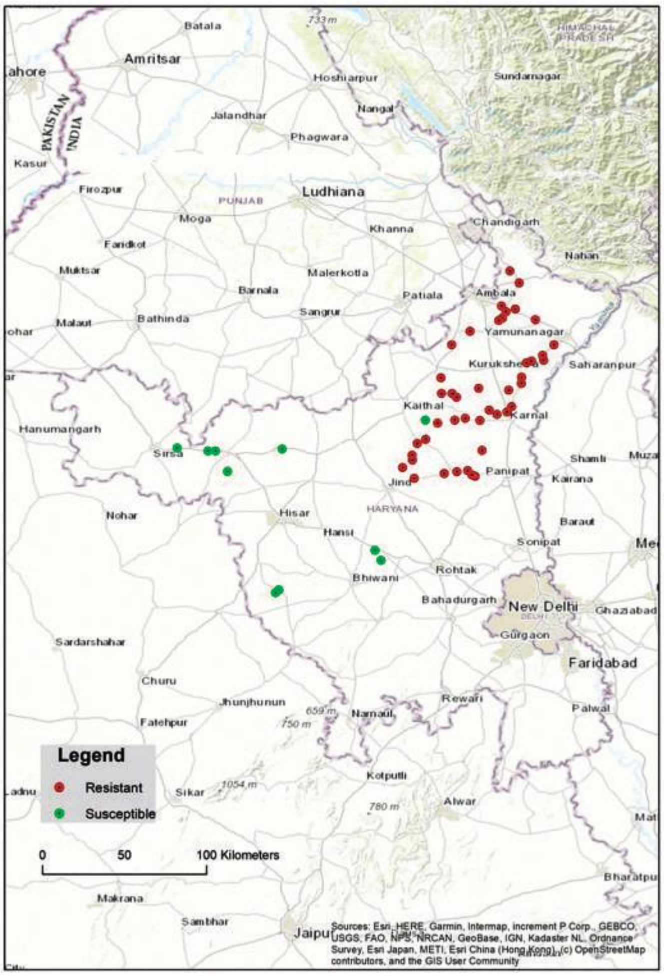
**Keywords:** Herbicide resistance, *Rumex dentatus*, Wheat, Weeds

WHEAT is an important staple food crop of India. Punjab and Haryana are the major wheat growing states of India as both share common agro climatic conditions, good availability of natural resources such as inherent fertile soil and adequate availability of water for irrigation. Weeds are the major concern that reduce the potential productivity of the wheat crop.

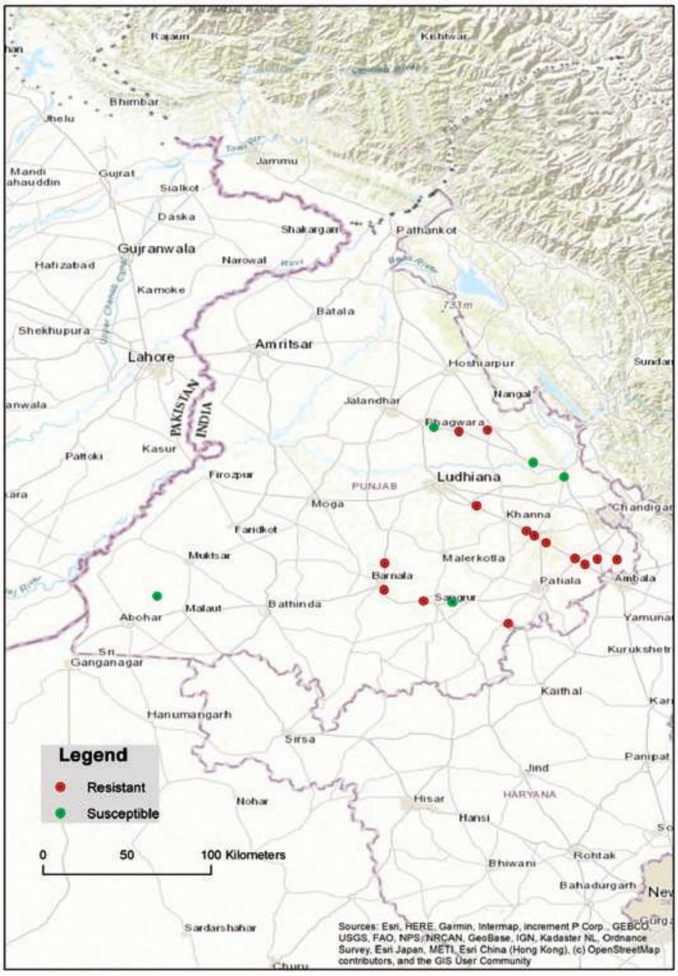
### Resistance issues in North-West India

Herbicides are recognized as the major tool for weed management along with other cultural and mechanical measures. But accelerated selection pressure associated with over reliance on herbicides with similar mode of action has led to increase in cases of herbicide resistance. *Rumex dentatus* is the dominant broadleaf weed of *rabi* season particularly in rice-wheat cropping system in Punjab and Haryana. Wheat crop is more prone to *R. dentatus* competition as compared to *Phalaris minor* because of its high biomass and superior growth than wheat. *R. dentatus* leads to 2-70% yield loss in wheat grain yield when its density increased from 5 plants/m$^2$ to 30 plants/m$^2$. Metsulfuron methyl herbicide has


*Rumex dentatus* biotype with graded doses of metsulfuron methyl.




Locations for resistant *Rumex dentatus* biotypes collected from Haryana.




Locations for resistant *Rumex dentatus* biotypes collected from Punjab

been used for controlling the *R. dentatus* in wheat crop since 1998. Due to its continuous use, it has shown resistance against metsulfuron. Earlier in India, herbicide resistance was confined to only *P. minor* in wheat against photosystem II (PS II) inhibitors (isoproturon), ACCase inhibitors (diclofop-methyl, pinoxaden, clodinafop-propargyl, fenoxaprop-P-ethyl), ALS inhibitors (mesosulfuron-methyl, sulfosulfuron, iodosulfuron-methyl-sodium, mesosulfuron-methyl, pyroxsulam).

### Confirmation of Resistance

A study was conducted at Punjab Agricultural University, Ludhiana during 2018-19 and 2019-20 to confirm the herbicide resistance in *Rumex dentatus* L. (Jangli palak) to metsulfuron methyl. In this study, seeds of the putative herbicide resistant biotypes of *R. dentatus* were collected during both years from the farmers' field in March-April from Haryana and Punjab states where metsulfuron methyl was used continuously from many years without any herbicide rotation. Total 56 and 33 biotypes of *R. dentatus* from Haryana; 6 and 19 biotypes from Punjab were collected in first and second year, respectively. These biotypes were screened under pot study. The seeds of these biotypes were sown in pots in October and 10 plants were maintained in each pot. Graded doses 0, 5 g/ha (X) and

## Animal drawn multi-crop planter-cum-herbicide applicator

A three row multi-crop planter cum herbicide applicator was developed by AICRP on UAE (IGKVV, Raipur centre) for planting of seeds and application of herbicide simultaneously. It consists of a frame, seed hoppers, seed metering devices, seed delivery tubes, inverted T type furrow openers, sprayer tanks, boom and nozzles. Sprayer nozzles, seed metering mechanism, hoppers and seed delivery tubes are mounted on inverted T type furrow openers, and can be adjusted for row spacing of 230–240 mm. The performance of implement was evaluated for sowing of soybean, greengram and fodder maize crops. The effective field capacity for soybean, greengram and fodder maize was 0.183, 0.121 and 0.124 ha/h, respectively. Cost of the implement is ₹ 15,000. The cost of sowing operation per ha was ₹ 440, ₹ 666 and ₹ 650 for soybean, greengram and fodder, respectively.

*Source:* ICAR Annual Report (2020)

*R. dentatus* biotype with control (left), 2,4-D sodium salt 500 g/ha, 2,4-D ester 238 g/ha, carfentrazone ethyl 20 g/ha, metsulfuron methyl + carfentrazone ethyl 25 g/ha and halauxifen + fluroxypyr 240.6 g/ha at 20 DAT.

10 g/ha (2X) of metsulfuron methyl were applied at 3-4 leaves stage of *R. dentatus* using knapsack sprayer fitted with flat fan nozzle with discharge rate of 375 litre water per ha. Based on the reduction in the shoot biomass, growth reduction was calculated by comparing with the untreated control. Results revealed that 38 out of 56 biotypes of *R. dentatus* collected from Haryana in first year were resistant to metsulfuron, whereas only one biotype showed resistance from Punjab. Further, 23 biotypes out of 33 biotypes collected in second year were found resistant from Haryana whereas 14 biotypes out of 19 were found resistant in Punjab. This confirmed the resistance in *R. dentatus* against metsulfuron-methyl in different regions of Haryana and Punjab.

Earlier, some reports of resistance were only confined to Panipat district of Haryana, but this study confirmed the resistance from not only regions of Panipat but also in other areas such as Kaithal, Kurukshetra and Karnal districts. It implied the wider infestation of resistant *R. dentatus* in the state.

Further, this study also testified the infestation of metsulfuron methyl-resistant *R. dentatus* biotypes in Punjab for the first time. In Punjab, highly metsulfuron methyl-resistant biotypes of *R. dentatus* were found from Fatehgarh Sahib, Patiala and Hoshiarpur districts. The herbicide resistance in *R. dentatus* after *P. minor* in India is an alarming signal for the sustainable wheat production. Therefore, the use of metsulfuron-methyl is not economical for control of *R. dentatus,* where resistance has been confirmed.

### Management strategies

To control resistant weeds, integrated weed management through use of herbicides having alternate modes of action should be recommended. Further, preventive strategies such as use of certified weed free seeds, field scouting, clean farm equipments restricted movement of weed seeds within fields and field-to-field along with removal of weed seeds should be integrated with chemical measures.

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## Successful cultivation of bio fortified wheat variety WB-02 in district Bijnor, Uttar Pradesh

The area under wheat is about 145,000 ha in Bijnor district, out of that about 75,000 ha area is under timely sown condition. The variety WB-02 is rich in zinc (42 ppm) and iron (40 ppm) in comparison to 32 ppm zinc and 28 ppm iron in other wheat varieties with maturity of 138–140 days, bold grained, resistant against yellow rust and leaf blight. WB-02 was introduced and demonstrated by KVK Bijnor during *rabi* 2017–18 and 2018–19 at 25 farmers' field through OFT and FLD. Average yield at farmers field recorded was 57.50 q/ha (63.75 q maximum yield per ha) with cost of cultivation of ₹ 46,345/ha and net profit ₹ 91,605/ha. The area under this variety has now spread to more than 850 ha in just two years. Farmers are satisfied with the yield of this variety and also claim that it is better for chapatti making with higher enrichment of zinc and iron. The successful farmer is Sri Satish Kumar belonging to Sidiyawali village in Noorpur block of Bijnor district.


*Source:* ICAR Annual Report (2020)

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# Wheat Blast

## —A menace to wheat cultivation

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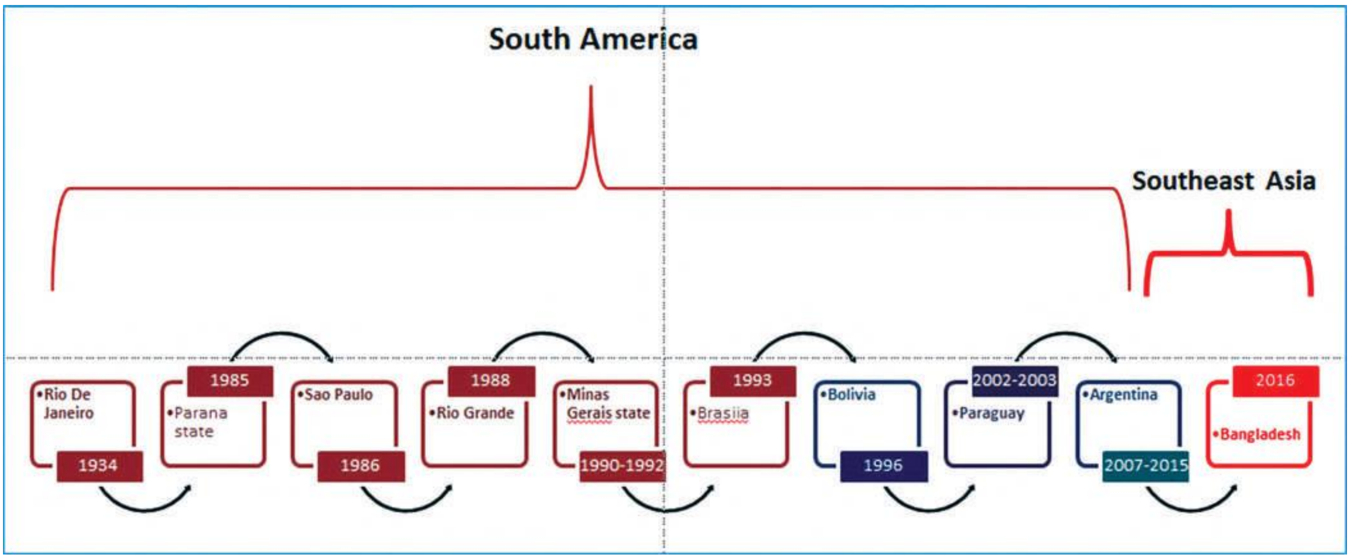
*The wheat blast fungi,* Magnaporthe oryzae *pathotype* triticum, *has more than 50 hosts to complete its life cycle. This disease was first reported from South America, Brazil. Sudden outbreak of this disease was reported in 2016 in Bangladesh. The states of Bangladesh near the border of West Bengal are at risk for cultivating wheat. This can be the cue for this pathogen to take entry into India. Therefore, care should be taken by implementing regular monitoring and continuous vigilance to prevent the entry of the pathogen in India.*

**Keywords:** *Magnaporthe* sp., Pathogen, Wheat blast

OUTBREAK of new disease causing agents and their increased frequency is a major menace towards global food security. One example is blast; a fungal disease of rice, wheat and other grasses that can destroy food supply sufficient to sustain millions of people. It can cause up to 100% yield losses under congenial environmental conditions. Till 1930, there was no historical report on occurrence of the blast disease of wheat. During 1985, wheat blast disease was reported and confined to the tropical regions of South America. Inefficient quarantine facility of the exporting and importing country is the only responsible factor for distant appearance of this disease. Moreover, erratic changes of climatic conditions combined with the global warming may trigger spread of this disease to rice-wheat growing areas in near future. It has now become a major threat to the wheat growing area of Bangladesh. Eventual movement to the Asian continent particularly Bangladesh in 2016 is likely to affect economic yield of wheat. Climatic condition of Bangladesh is more or less similar to India and Pakistan. Bangladesh also shares a long border with India which puts the wheat growing areas of India and Pakistan at risk. After 2016 in Bangladesh, it was unofficially reported from India in 2017.

### Symptoms

Initial symptom of spike infection is very much confusing with




Historical occurrence of the wheat blast pathogen symptoms of head blight disease incited by *Fusarium*. Unlike Fusarium head blight, instead of attacking each isolated spikelet, it infects the rachis. Initial pathogen invasion occurs to the rachis; either at the base or upper part, interrupting translocation of photosynthates above the point of infection and subsequent spikelet formation. Complete or partial bleaching of the spike above the point of infection with either no grain or shrivelled grain is common in affected plants. Commonly observed bleached or grey coloured heads with thin layer of fungal sporulation is indicative for successful infection. If infection starts at the mid region of spikelet, above portion of the infection remains bleached and no grains are formed while below portion remains healthy with normal grains. In case of severe infection, eye-shaped or spindle shaped necrotic lesions with grey centres on infected leaves may be observed.

## Pathogen biology and taxonomy

Anamorphic stage of the fungus is infectious and the name *Pyricularia* was given by Saccardoas as it produces pyriform shaped conidia. The genus *Pyricularia* so far has been identified on rice signifying its species name as *oryzae*, given by Cavara (1892). In 1970 the sexual spore of the genus *Pyricularia* was observed in laboratory on the leaves of *Digitaria* and designated as *Pyricularia grisea*. Based on host specificity; sexual compatibility and genetic similarity, *P. oryzae* isolates have been classified into several subgroups. These are the Oryza pathotype- pathogenic on rice (*Oryza sativa*), Setaria pathotype- pathogenic on foxtail millet (*Setaria italica*), Panicum pathotype-pathogenic on common millet (*Panicum miliaceum*), Triticum pathotype- pathogenic on wheat (*Triticum aestivum*), Eleusine pathotype- on finger millet (*Eleusine coracana*), Lolium pathotype-pathogenic on perennial ryegrass (*Lolium perenne*) and Avena pathotype- pathogenic on oats (*Avena sativa*). But this basis of classification was not fruitful for a long time because pathogenicity test of the many pathotypes has revealed broader host range. For example, isolates of Triticum pathotype can cause disease on oats, barley and rye; similarly, lolium and avena pathotype can infect wheat. The rice-infecting isolates of *M. oryzae* are not pathogenic on wheat and genetically different from wheat infecting populations of *M. oryzae*. Therefore, the wheat blast pathogen was named as *Pyricularia graminis tritici* (Pygt). *Pyricularia oryzae (Magnaporthe oryzae)* designated as a single species with multiple lineages and limited primary host whereas, wheat infecting *Pyricularia* species has large host range and high genetic variations. The reason behind the huge difference between rice-infecting *Pyricularia* and wheat-infecting *Pyricularia* regarding host range and new host adaptation is mutations in avirulence gene *PWT3* and *PWT4*. A recent study based on multi-gene phylogenetic analysis of blast causing isolates revealed that there are two species causing wheat blast- *Pyricularia graminis tritici* (Pygt) and *Pyricularia oryzae pathotype triticum* (PoT) both of which are independent to *Pyricularia oryzae; a* pathogen of rice. The wheat blast pathogen of Bangladesh is similar to South American isolate of wheat blast that has been recognized as *Pyricularia graminis tritici* (Pygt).

## Epidemiology

Occurrence of the disease symptom is associated with high humidity and average temperature ranges between 18°-25°C during flowering stage followed by hot-humid, sunny weather for several days.

## Management

For a long time the disease was endemic to Brazil and later it became sporadic. Due to high variability and large host range there is a chance to be epidemic. It will be difficult to find resistance source because of its high variability. In this context, integrated management practices can be a good strategy to manage this disease.

***Reinforcement of strong quarantine facilities***: Sudden outbreak of Brazilian pathotype of wheat blast pathogen in Bangladesh is the consequence of spread to inefficient legislative measures. Earlier also the pathogen spread to Bolivia, Paraguay and Argentina from imported Brazilian seed lot. The rigorous vigilance and detection method can decrease the further spread of the pathogen.

***Use of healthy seeds***: As the pathogen is seed borne, spore can remain viable up to two years both on surface and inside the seed. Healthy and certified seeds should be used.

***Field sanitary practices***: The pathogen produces perithecia on crop residues. Weeds serve as connecting bridges between two growing seasons and also source of primary inoculum. Therefore, clean cultivation practices should be adopted to break the continuity of life cycle of the pathogen.

***Deep ploughing***: Deep ploughing can be implemented to reduce the primary source of inoculum by burying crop residues into deeper soil layer.

***Eradication of weed hosts***: Elimination of certain weed hosts like *Brachiaria* spp., *Cenchrus* spp., *Chloris* spp., *Digitaria* spp., *Echinochloa* spp., *Eleusine indica* and *Lolium* spp. will be helpful for reducing primary inoculum load.

***Crop rotation***: Crop rotation with non-grass crops like soybean, potato, jute cultivation could be followed.

***Alternate date of Planting***: Planting should be done in such a way that early flowering and heading of crops will not coincide with the favourable weather of wheat blast pathogen infection.

***Breeding for host resistance***: Because of high variability and extensive host range, development of resistant cultivar is vital. Gene deployment can be done to encounter the gene flow within the population of different pathotypes.

***Chemical treatment***: Seed treatment and spraying of chemicals combining strobilurins and triazole fungicides from flowering to heading stage will give better results.

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*Indian Farming* **72**(1): 11–13; January 2022

# Sugarcane Jaggery:

## An alternative of sugar for healthy living

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*India is the world's largest sugar and sugarcane producer. More than 70% of global production is done in India, with 53% being processed into white sugar, 36% into jaggery and khandsari, 3% for chewing as cane juice, and 8% as seed cane. India is world's leading jaggery producer and user. Sugarcane jaggery, often called "gur" is a natural, traditional, and nutritious sweetener made by concentrating sugarcane juice. It is a non-centrifugal, unprocessed sugar that contains all of the minerals and vitamins found in sugarcane juice. Jaggery is made by condensing sugarcane juice and it comes in solid blocks and granulated form. Granulated jaggery is becoming popular due to its ease of handling, packaging and storage. Although the methods for converting sugarcane and producing sugar, gur and khandsari varies, the creation of these consumable end products adds a significant amount of value. Millions of individuals will be able to find work as a result of this. Jaggery and khandsari have resisted competition while also addressing ethnic desires and maintaining farmers' interests. Jaggery is traditionally made on the farm by cane producers. With the arrival of new entrepreneurs that embarked into jaggery manufacturing as a pure business by purchasing cane from cane growers, this tendency has shifted. Some hurdles such as significantly higher price, prompt disbursements for the sale of cane, failure to register with the factory on time, delays in cutting orders, untimely payments are responsible for the farmers to prepare the jaggery from canes and sell it directly to the users.*

**Keywords:** Farmers, Gur, Jaggery, Sugarcane

GUL, gud, gur, vellum, and bella are all names for jaggery, which is made in various parts of our country. Jaggery is actually more complex than sugar, since it is made up of longer chains of sucrose. As a result, it is digested more slowly than white sugar, which quickly releases energy. Slower release of energy is beneficial for the human body. Unfortunately, since it is a source of sugar, it has not been proven to work for diabetic patients. Because jaggery is made in iron vessels, it collects a significant amount of ferrous salts, which is beneficial to anaemic people. Jaggery is healthy for the human body because it contains mineral salts that come from sugarcane. Jaggery cleanses the lungs, stomach, intestines, oesophagus and respiratory systems since it is a cleansing agent. Furthermore, those exposed to high levels of dust in their daily activities, it is recommended that they drink it, which protects them from ailments such as asthma, cough and cold, chest congestion and so on. Gur is used for a variety of things, including serving as a welcome drink to visitors, preparing reori, gazak, chikki, patti and other dishes, as cattle fodder and in distilleries and pharmaceutical production facilities. Gur is now used in a variety of confectionery products. Gur can also be found in the leather and tobacco industries. In addition, Gur is provided to workers in cement plants and coal mines to prevent dust allergies.

### Nutritional value and uses of jaggery

Gur is a high-calorie sweetener that is known to be healthier than white sugar since it contains minerals, proteins, glucose and fructose. A high quality gur has more than 70% sucrose, less than 10% glucose and fructose, less than 5% minerals and less than 3% moisture. It is rich in minerals such as Calcium (40-100 mg), Magnesium (70-90 mg), Potassium (10-56 mg), Phosphorus (20-90 mg), Sodium (19-30 mg), Iron (10-13 mg), Manganese (0.2-0.5 mg), Zinc (0.2-0.4 mg), Copper (0.1-0.9 mg), Chloride (5.3 mg), Vitamin A (3.8 mg), Vitamin B1 (0.01 mg), Vitamin B2 (0.06 mg), Vitamin B5 (0.01 mg), Vitamin B6 (0.01 mg), Vitamin C (7.00 mg), Vitamin D2 (6.50 mg), Vitamin E (111.30 mg), Vitamin PP (7.00 mg), and Protein (280 mg per

100 g of jaggery). Hence, it could serve as a source of nutrition for people suffering from mal-nutrition and undernutrition.

## Preparation of jaggery (Gur)

After considering nutritional value of jaggery along with regular income, it is essential to train the cane farmers with scientific, tested and recommended techniques. Further, for earning higher profits, value addition can be done by adding dry fruits such as groundnut, sesame (til) and packaging training is also a must. Punjab Agricultural University, Ludhiana and Regional Research Station, Kapurthala, Punjab frequently provides training on these aspects to the farmers. Different steps involved in jaggery preparation are given here.

Jaggery varieties obtained from different cane cultivars

- *Juice Extraction from the harvested canes*: This is the first important step towards better jaggery. For extracting the maximum juice from the canes, a three mill roller sugarcane crusher should be preferred. Afterwards, the crushed juice is filtered with muslin cloth to remove bagasse and other suspended solids.

**Table 1.** Relative performance of varieties for good quality jaggery preparation

| Characteristic/ Variety | CoPb 92 | Co 118 | CoJ 85 | CoJ 88 |
|---|---|---|---|---|
| Maturity group | Early | Early | Early | Mid-late |
| Cane colour | Purple green | Purple green | Green | Greyish green |
| Cane thickness | Medium thick | Thick | Thick | Medium thick |
| Sucrose per cent in December | 18.0 | 17 | 18.0-18.5 | 17.0-18.0 |
| Colour | Yellow | Dark Brown | Light brown | Golden yellow |
| Taste | Sweet | Sweet | Sweet | Sweet |
| Hardness | Hard | Hard | Hard | Hard |
| Storage life | Longer storage life | Longer storage life | Average storage life | Longer storage life |
| Ratoonability | Good | Average | Average | Excellent |
| Cane yield | 335 qtl/acre | 320 qtl/acre | 305 qtl/acre | 335 qtl/acre |

**Table 2.** Comparative evaluation of jaggery and sugar

| Jaggery | Sugar |
|---|---|
| It is far complex and is made up of longer chains of sucrose | It is simplest available form of sugar |
| It is digested slower than sugar and releases energy slowly | It is instantly absorbed in blood and releases a burst of energy |
| It is rather a tastemaker and colour maker | It is just a sweetener |
| It contains iron, calcium, potassium, phosphorus | It is a source of empty calories |
| Jaggery helps in calcium absorption | Sugar interferes with absorption of calcium and magnesium |
| Jaggery is eco-friendly | Sugar industry pollutes air, water and soil |
| Jaggery aids digestion, on its consumption becomes alkaline in the digestive system | Sugar becomes acidic |

- *Juice clarification*: After extraction, sugarcane juice is to be clarified, which further helps in the proper crystallization and solidification of sugar, to have a better product. Under this step of juice clarification, emulsion is prepared from the bark of the Sukhlai after soaking it in water for 24 hours. Afterwards, bark is rubbed to obtain a thick mucilaginous fluid, which is then added in the boiling juice when the scum begins to rise. As per one estimate, around one litre emulsion is sufficient to clarify 100 litres of sugarcane juice. Beside the use of Sukhlai emulsion, extract of various plants (Okra, Masak dana, Phalsa etc.) or certain chemicals (lime water, sodium carbonate, sodium bicarbonate, dum, citric acid, potassium metabisulphite) are added when juice starts boiling. Juice is boiled extensively to concentrate it to 60° brix.
- *Cane juice boiling and concentrating*: The extracted and clear juice is now transferred to a boiling pan up to 1/3rd of its volume. Firstly, juice is boiled slowly up to its boiling temperature at 85°C, the dirt along with nitrogenous compounds coagulates and floats on the surface

as scum, which must be removed before juice starts boiling. Afterwards, juice is boiled vigorously for 2.5 to 3.0 hours to evaporate the water for concentrating the syrup. After attaining temperature of 100°C, flame should be reduced till the concentrated juice reaches the striking point (114-116°C) for gur and (120-122°C) for Shakkar making.

- *Moulding and packaging*: After attaining the striking point, material is transferred to wooden or aluminum moulds where after cooling, it solidifies. Afterwards, it could be moulded into different shapes using specially designed moulds or khurpa.

### Suitable time for jaggery preparation

Jaggery preparation is not carried out throughout the year as it requires mature canes. Generally, this operation starts from November and continues up to April. However, for best quality jaggery, selection of cane cultivars and time of jaggery preparation matters a lot. From early and mid-late sugarcane cultivars, the best time for jaggery preparation starts from November and December, and January to April, respectively.

### Value addition and storage of jaggery

For value addition, jaggery is blended with different natural flavours and taste additives like ginger, black pepper, cardamom, till and peanuts. Jaggery should be air dried before storing. From storage aspects, at household levels it is traditionally stored in earthen pots, wooden boxes, metal drums, polythene bags, etc. To avoid microbial infestation during the rainy season, jaggery should be stored at low temperature (4°C-9°C). Under any condition, for maintaining good jaggery quality, while storing the moisture content should not exceed 6% and be kept at a relative humidity of 43–61%.

### Sugarcane cultivars and jaggery quality

Selection of a good cane cultivar is a must for having the quality jaggery. In Punjab's climatic conditions for eating and keeping the quality of Gur, best cane cultivars recognized are CoPb 92, Co 118, CoJ 85 and CoJ 88.

## SUMMARY

Jaggery is better than sugar as far as nutritional values are concerned. Jaggery preparation not only provides additional nutrients in our diet but also adds to the overall income of the farmers which further improves their livelihood. Majority of the farmers produce jaggery with minimal capital input without caring about the scientific technique of jaggery preparation with value addition and also ignore the selection of sugarcane cultivars. Further, it is also critical to protect farmers' profits by increasing both quantity and the quality of their jaggery units with value addition and current technology for packaging and jaggery-based products.

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### Impoved varieties of Sugarcane (*Saccharum* sp. Hybrid)

| | | |
|---|---|---|
| CoC 13339 | Tamil Nadu, Andhra Pradesh and Odisha (Coastal areas) | Suitable for irrigated areas, average cane yield: 117.97 t/ha, moderately resistant to red rot and YLD, moderately resistant to smut. |
| Karan 14 (Co 13035) | Haryana, Rajasthan, Punjab, Uttarakhand and Central and Western Uttar Pradesh | Suitable for mid-late group for North-West zone, average cane yield 86.76 t/ha, Reaction to red rot is resistant to moderately resistant, least susceptible to shoot borer, top borer and stalk borer. |
| Sahaj-3 (CoS 12232) | Punjab, Haryana, Uttarakhand, Rajasthan and Central and Western Uttar Pradesh | Suitable for medium and high fertility soil under irrigated areas, average cane yield: 88.86 t/ha moderately resistant reaction to red rot and smut. |
| Sankalp (Co 12009) | Tamil Nadu, Kerala, Interior Andhra Pradesh, Telangana, Karnataka, Gujarat, Maharashtra, Madhya Pradesh and Chhattisgarh | Suitable for irrigated conditions, average cane yield: 119.65 t/ha, moderately resistant reaction to red rot, smut and YLD, less moderately susceptible to shoot fly and highly susceptible to internode borer. |

*Source:* ICAR Annual Report (2020)

*Indian Farming* **72**(1): 14–15; January 2022

# Efficient weed management

## through appropriate herbicides in groundnut

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*In groundnut cultivation, several factors cause yield losses, weeds contribute about 40% in yield reduction. Krishi Vigyan Kendra Chhatarpur initiated a systematic and comprehensive effort to solve the most severe weed problem in groundnut cultivation through appropriate weed management. Application of appropriate herbicides i.e. Imazethapyr 10% SL @ 100 g a.i./ha + Quizalofop-ethyl 5% EC @ 37.5 g a.i/ha at 15-20 days after sowing along with use of appropriate nozzle and volume of solution. By adopting appropriate herbicide for weed management practices, farmers received higher yield (6.7q/ha) that fetched higher income (₹ 32,243/ha) due to reduction of weed density (93.6%) as compared to farmers' practices. Appropriate weed management practices help in efficient utilization of available resources and improve the product quality of groundnut crop.*

**Keywords:** Groundnut, Herbicide, Weed management

GROUNDNUT (*Glycine max* L.) is one of the most important leguminous crops which contains about 44-50% oil and 22% protein. In India, it is cultivated in 39.31 lakh ha area with an annual production of 43.2 lakh MT. Groundnut is not only seen as an oil plant but also used for various purposes and can be grown in diverse environments throughout the world. Despite the high potential for rainfed groundnut production, low productivity is reported in these areas which has been ascribed to crop-weed competition and soil factors. In order to optimize groundnut yield, it is necessary to reduce the crop-weed competition with an efficient utilization of the given and available resources.

Weeds are one of the major resource consuming and limiting factors in groundnut production and cause substantial qualitative and quantitative losses in crop yield which may range from 25-45%. Degree of losses in groundnut yield depends on the type of weed flora, their density and duration of competition for nutrient, water, light and space. Generally, farmers use inappropriate chemical herbicides (Imazethapyr 10% SL @ 70 g a.i./ha or Quizalofop-ethyl 5%EC @ 20 g a.i/ha) for the management of weeds, however, due to poor knowledge about the use of appropriate herbicides, their dose, time and method of application, it becomes less effective. Besides these, farmers do not use the appropriate nozzle for spraying of weedicides. They generally use hollow cone nozzle instead of flat fan nozzle for spraying herbicides which significantly reduces the mortality of weeds, even after appropriate herbicides are being used. It has also been observed that farmers do not use recommended volume of solution which is necessary for a particular area, such as 200 litres of solution that facilitates the weed plants to be saturated sufficiently to cover an acre of land for effective control of weeds. If the recommended volume of solution is not applied, it will reduce the mortality of weeds significantly.

**Table 1.** Effect of herbicidal weed management in Groundnut

| Technology | Yield q/ha | Cost of cultivation/ha | Gross return (₹/ha) | Net return (₹/ha) | Additional income (₹/ha) | B:C Ratio | Weed density/m² | Weed control efficiency (%) |
|---|---|---|---|---|---|---|---|---|
| Imazethapyr 10% SL @ 70 g a.i./ (Farmers Practices) | 9.5 | 37700 | 50112 | 12412 | 32243 | 1.3 | 78.5 | |
| Imazethapyr 10% SL @ 100 g a.i./ha + Quizalofop-ethyl 5% EC @ 37.5 g a.i/ha (Recommended Practices) | 16.2 | 40800 | 85455 | 44655 | | 2.1 | 5 | 93.6 |

### Performance

Verification trials (FLD) on weed management on the farmers' field recorded increase in production up to 6.7 q/ha which raised income of ₹32,243 per ha (Table 1) against their own traditional practices. Farmers were encouraged with these results and in next year they adopted same practice on their own on the whole groundnut area. Significant growth in yield, additional income, B:C ratio and reduction in weed density (93.6%) were recorded with the new technology as compared to farmers' traditional practices. This module effectively controls weeds at an early stage by using appropriate herbicides at 15-20 days after sowing, which results in reduction of the infestation of remaining weeds and ultimately reduces the crop-weed competition that leads to increase in yield of groundnut.

Impact of appropriate herbicide on weed infestation and pod development

Complete weed management in groundnut under appropriate herbicides

Benefits integrated with weed management are given here.

### Saving natural resources

Low dose of weedicide leads to poor management of weeds, which causes high competition for water and sunlight between crop and weeds, resulting in low yield of groundnut. While overdose of weedicide leads to pollution in soil, water and environment as well as damage the crops, which results in low yield. Therefore, all groundnut growers should use an appropriate dose of herbicides.

### Improved product quality

Due to integrated weed management practice, attack of other pests was significantly minimized and the quality of produce was better in terms of grain size, boldness of seeds and seeds were free from weeds. In contrast, under farmers' traditional practices, grain size is reduced along with contamination and objectionable weed seeds.

## SUMMARY

It can be stated that the imazethapyr along with quizalofop-ethyl can effectively control different categories of weeds in groundnut field. Higher economic yields may be achieved in groundnut crop without any phytotoxic effect under the treatment (Imazethapyr 10% SL @ 100 g a.i./ha + Quizalofop-ethyl 5% EC @ 37.5 g a.i/ha at 20 DAS), where crops matured earlier than the control plots.

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### Power operated groundnut stripper-cum-decorticator

Groundnut is the sixth most important oilseed crop in the world. An effort was made to combine the stripping and decortication operation and a small 0.5 hp motor operated groundnut stripper cum decorticator was developed. The equipment can be used only for stripping or stripping-cum-decortications purpose. The height of the hopper was kept as 93 cm considering the anthropometric body dimensions of female agricultural workers. In a manual stripper four women can strip 11 kg of pods in one hour. The developed power operated groundnut stripper has average output capacity of 12.1 kg/h and it needs only one operator, saving time as well as labour. The threshing efficiency is around 95% and the total pod losses lies within 5%. The cleaning efficiency is 70%, which can be enhanced by adding a blower mechanism.

*Source:* ICAR Annual Report (2020)

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# Production trend of herbicides

## vis-à-vis other pesticides in India

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*Pests are the reason for severe crop losses around world leaving millions of people without enough food to eat. Pests adversely impact the primary source of income of rural poor. Weed menace is considered as a serious problem in Indian agriculture. Weeds are not only yield reducers, but in many instances, economically more harmful than other crop pests like insects, fungi etc. Chemical method or use of herbicides is considered as the most effective and easiest method of weed management. Production trend of herbicides in relation to other pesticides during the period from 2015-16 to 2019-20 gives a deep insight. The total pesticide production was increasing till 2018-19 and declined by 25 thousand MT in 2019-20 as compared to the previous year whereas herbicide production showed a meagre decline of 3 thousand MT in production during the same period. Compound annual growth rate calculation indicated that highest growth rate of production (4.7%) was registered by herbicides among other group of pesticides. Further, herbicide production share in total pesticides has increased from 17% in 2015-16 to 20% in 2019-20 whereas declining trend was observed in case of fungicides. Barring glyphosate, all other key herbicides depicted a positive compound annual growth rate from 2015-16 to 2019-20 and metribuzin recorded highest (30.68%) growth rate among others.*

**Keywords:** Glyphosate, Growth rate, Herbicides, Metribuzin, Pesticides, Weeds

PEST refers to any animal or plant causing harm or damage to people or their animals, crops or possessions, even if it only causes annoyance. Wide range of organisms including insects, mites, rodents, slugs, snails, nematodes, cestodes, weeds, fungi, bacteria and viruses are considered as pests in agriculture. These pests cause huge crop yield loss every year. As much as 40% of the world's agricultural crops are lost to pests each year. Further, invasive pests cost countries at least $70 billion annually and are one of the main drivers of biodiversity loss, according to estimates from the Food and Agriculture Organization of the United Nations (FAO). Serious damage caused by these pests leaves millions of people without sufficient food to eat and it adversely impacts the primary source of income of rural poor. About 30-40% of annual crop yield in India is getting wasted due to various agricultural pests. Pesticides play major role in controlling various pests in agriculture up to certain extent and thereby prevent crop damage to cent-percent level. The term pesticide covers a wide range of compounds including insecticides, fungicides, herbicides, rodenticides, molluscicides, nematicides, plant growth regulators and others. Worldwide, 40% of pesticide use is contributed to herbicides, 17% to insecticides and 10% to fungicides. By using pesticides to ensure maximum crop yield, farmers are able to save money. Some estimates suggest there is a four time return on pesticide investments.

Weeds are considered a serious menace in agriculture. Crop yield loss due to weeds in India is estimated to be about US $11 billion every year. If we do not control weed growth at critical stage, it may cause crop loss as high as 70%. A study conducted on 10 major crops revealed these statistics. Weeds are not only yield reducers, but in many instances, economically more harmful than insects, fungi or other crop pests. Introduction of selective herbicides in late 1940s and subsequent discovery of new herbicide molecules provided a wonderful tool of weed management to farmers called "Chemical hoe". Herbicides continue to be one of the most effective and easiest tools for weed management in India as well as world. Though there are growing environmental concerns over the intensive use of herbicides,

**Table 1.** Countrywise pesticide use

| Rank | Country | Pesticide use (tonnes) | Pesticide per hectare of crop land (kg) |
|---|---|---|---|
| 1 | China | 1763000 | 13.1 |
| 2 | United States | 407779 | 2.5 |
| 3 | Brazil | 377176 | 6 |
| 4 | Argentina | 196009 | 4.9 |
| 5 | Canada | 90839 | 2.4 |
| 6 | Ukraine | 78201 | 2.3 |
| 7 | France | 70589 | 3.6 |
| 8 | Malaysia | 67288 | 8.1 |
| 9 | Australia | 63416 | 2 |
| 10 | Spain | 60896 | 3.6 |
| 11 | Italy | 56641 | 6.1 |
| 12 | Turkey | 54098 | 2.3 |
| 13 | India | 52750 | 0.3 |
| 14 | Japan | 52249 | 11.8 |
| 15 | Germany | 48193 | 4 |
| | Average | 229275 | 4.9 |

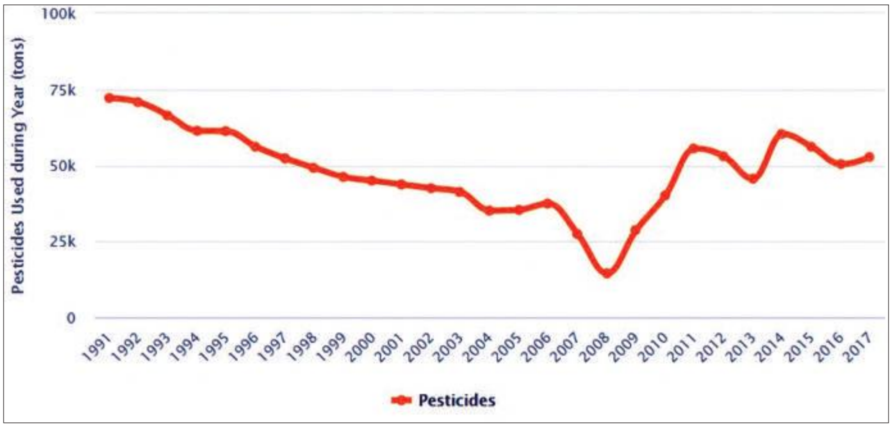
*Source*: FAO stat, www.worldometers.info

there is no better and effective alternative. Nevertheless, judicious use of herbicides for weed management has a significant place in Indian agriculture particularly considering large chunk of small and marginal farmers in the country.

## Pesticide use in India

Table 1 depicts countrywise pesticide use in the world. Top 15 countries are ranked on basis of total pesticide use (as of 2017). China tops the chart with 17,63,000 tonnes of pesticides and per hectare usage of 13.1 kg, which is remarkably high as compared to other countries. The United States is the next largest consumer of pesticides. It used 4,07,779 tonnes of pesticides with a per hectare usage of 2.5 kg. Pesticides are so common in United States that even common citizens apply them to lawns, and municipalities use them for parks.

India's global ranking is 13th in terms of total pesticide use (52,750 tonnes) and the per hectare usage is just 0.3 kg. Both total usage as well as per hectare usage of pesticides is very much low in India as compared to other countries and the average data. In terms of per hectare crop land, India occupies 113th rank among other countries in the world. Further, if we look at the period from 1991 to 2008, overall decline was




Trend of annual pesticide use in India (1991 to 2017) (*Source*: FAO stat and www.worldometers.info after 2008)

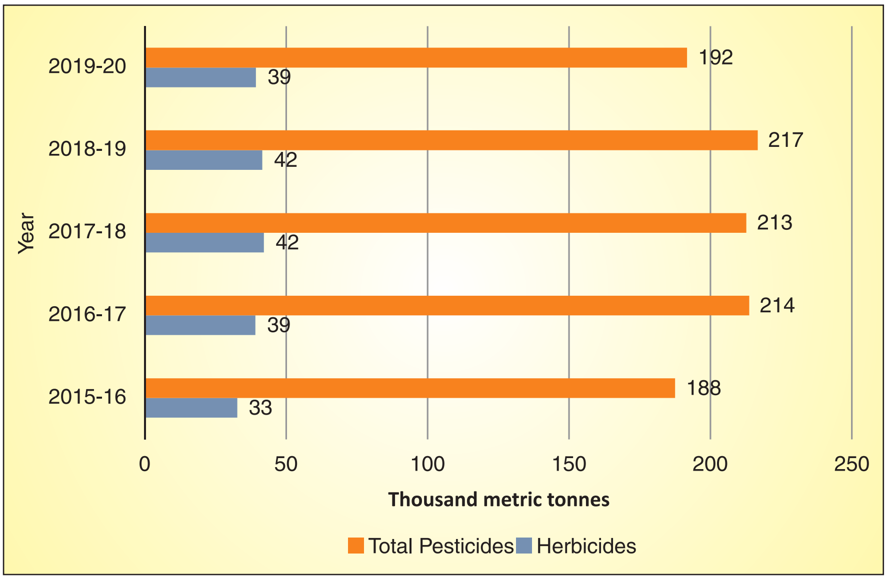
observed in annual pesticide usage trend in India. However, after a steep decrease from 37,423 tonnes in 2005 to 14,485 tonnes in 2008, the per year usage of pesticide in India has witnessed an increasing trend and it reached 52,750 tonnes in 2017. Though there was slight dip of usage in 2012 and 2013, an overall increasing trend could be seen in annual pesticide use in India (1991 to 2017).

## Volume of production in India: Herbicide vis-à-vis total pesticides

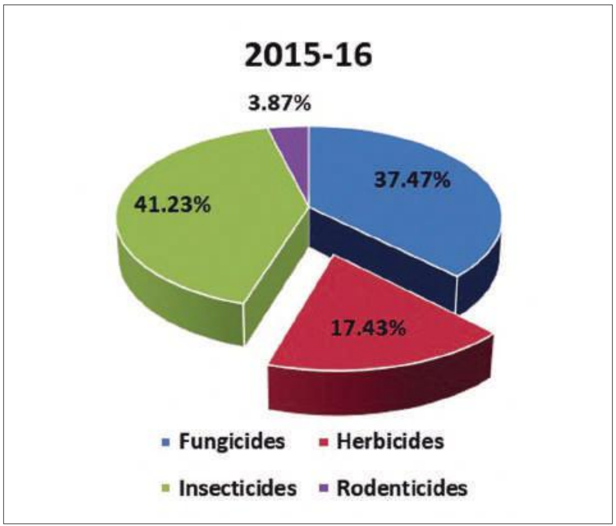
It was indicated that total pesticide production has increased from 188 thousand MT in 2015-16 to 192 thousand MT in 2019-20. However, the highest production (217 thousand MT) was observed in 2018-19. It was on increasing trend till 2018-19 and showed decline of 25 thousand MT in 2019-20 as compared to the previous year. Production volume of herbicides also indicated similar trend during this period. It was 33 thousand MT in 2015-16 and reached 39 thousand MT in 2019-20. Highest production (42 thousand MT) was observed in both 2017-18 and 2018-19. A dip of 3 thousand MT was recorded in 2019-20 as compared to previous year.

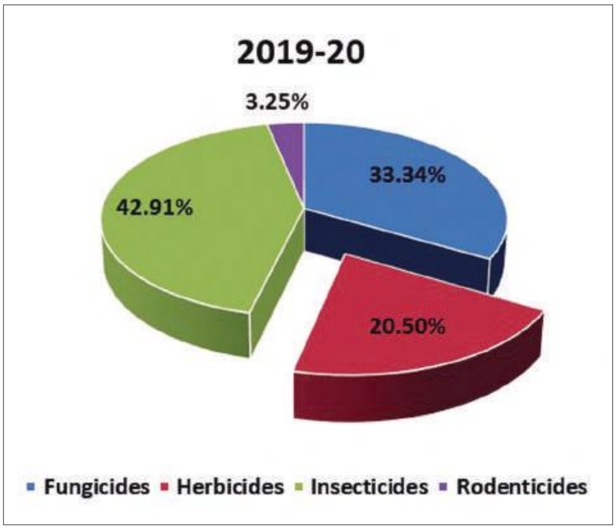
## Position of Herbicides in Pesticide Group

Total pesticide production in the country depicted a compound annual growth rate of 0.56 during 2015-16 to 2019-20 (Table 2). Production of herbicides topped with 4.72% followed by insecticide with 1.57%. Interestingly, fungicides and rodenticides showed negative growth




Volume of herbicides and total pesticides produced in India from 2015-16 to 2019-20 (*Source*: Department of Chemicals & Petro-Chemicals, Ministry of Chemicals & Fertilizers)




Percent share of different pesticide groups in total volume of pesticides produced in 2015-16 and 2019-20. (*Source*: Department of Chemicals & Petro-Chemicals, Ministry of Chemicals & Fertilizers)

rate of -2.33% and -3.72% respectively. Further, we could say that, the dip in total pesticide production observed in 2019-20 is mainly due to the decreased production of fungicides and insecticides. Banning of various pesticide molecules in recent past could be the reason for registering the declined production. Percent share of different pesticide group for the year 2015-16 and 2019-20 showed more or less similar pattern in terms of percent share of production. Insecticides occupied the top position with more than 40% followed by fungicides with more than 30% in both the years. However, herbicides production share has increased from 17% in 2015-16 to 20% in 2019-20 whereas fungicides production share has declined from 37 % to 33 % during this period.

### Production Trend of key Herbicides in India

Volume of production and compound annual growth rate of key herbicides produced in India is given in Table 3. Only the key herbicides for which time series data were available have been considered for this analysis. Perusal of the table indicates that all these key herbicides together recorded a compound annual growth rate of 6.3% during 2015-16 to 2019-20. Barring Glyphosate, all other herbicides showed a positive growth rate of production during this period. Of the six key herbicides, Metribuzin registered highest growth rate (30.68%) followed by Diuron (28.14%) and Pretilachlor (12.11%). In terms of volume production, 2,4-D contributed highest with more than 22 thousand MT followed by Glyphosate (5.9 thousand MT) and Diuron (3.4 thousand MT).

**Table 2.** Production trend of different pesticide group during the period 2015-16 to 2019-20

| Pesticide group | Volume of production (in thousand metric tonnes) | | | | | CAGR (%) |
|---|---|---|---|---|---|---|
| | 2015-16 | 2016-17 | 2017-18 | 2018-19 | 2019-20 | |
| Fungicides | 70.261 | 81.812 | 73.743 | 72.883 | 63.936 | -2.33 |
| Herbicides | 32.687 | 39.117 | 42.114 | 41.56 | 39.307 | 4.72 |
| Insecticides | 77.324 | 85.077 | 90.676 | 96.087 | 82.282 | 1.57 |
| Rodenticides | 7.25 | 7.712 | 6.166 | 6.173 | 6.23 | -3.72 |
| Grand Total | 187.522 | 213.718 | 212.699 | 216.703 | 191.755 | 0.56 |

*Source*: Department of Chemicals & Petro-Chemicals, Ministry of Chemicals & Fertilizers.

**Table 3.** Compound annual growth rate of key herbicides production in India

| Herbicide | Volume of production (in thousand metric tonnes) | | | | | CAGR (%) |
|---|---|---|---|---|---|---|
| | 2015-16 | 2016-17 | 2017-18 | 2018-19 | 2019-20 | |
| 2,4-D | 18.46 | 23.36 | 25.83 | 24.24 | 22.56 | 5.14 |
| Atrazine | 1.21 | 1.90 | 2.25 | 1.48 | 1.73 | 9.35 |
| Diuron | 1.26 | 3.68 | 3.26 | 3.62 | 3.40 | 28.14 |
| Glyphosate | 6.96 | 6.35 | 6.29 | 6.68 | 5.91 | -4.00 |
| Metribuzin | 0.91 | 1.12 | 0.88 | 1.92 | 2.65 | 30.68 |
| Pretilachlor (Technical) | 1.94 | 2.58 | 3.60 | 3.63 | 3.07 | 12.11 |
| Total | 30.74 | 38.99 | 42.11 | 41.56 | 39.31 | 6.34 |

*Source*: Department of Chemicals & Petro-Chemicals, Ministry of Chemicals & Fertilizers.

## SUMMARY

Pesticide use in India is very low as compared to other countries. All group of pesticides and herbicides have an important role to play in Indian agriculture. Herbicides or chemical method of weed management is considered as the most effective tool to deal with the weed menace in crops. The pesticide market in India is one of the billion rupees markets of the country. Hence, understanding the production trend of various herbicides in relation to the other group of pesticides has great significance. It would help provide an overall picture of domestic production scenario of herbicides which in turn will help forecast supply-demand gap of the same.

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*Indian Farming* **72**(1): 19–22; January 2022

# Smart Fertilizers

## —A boon for Indian agriculture

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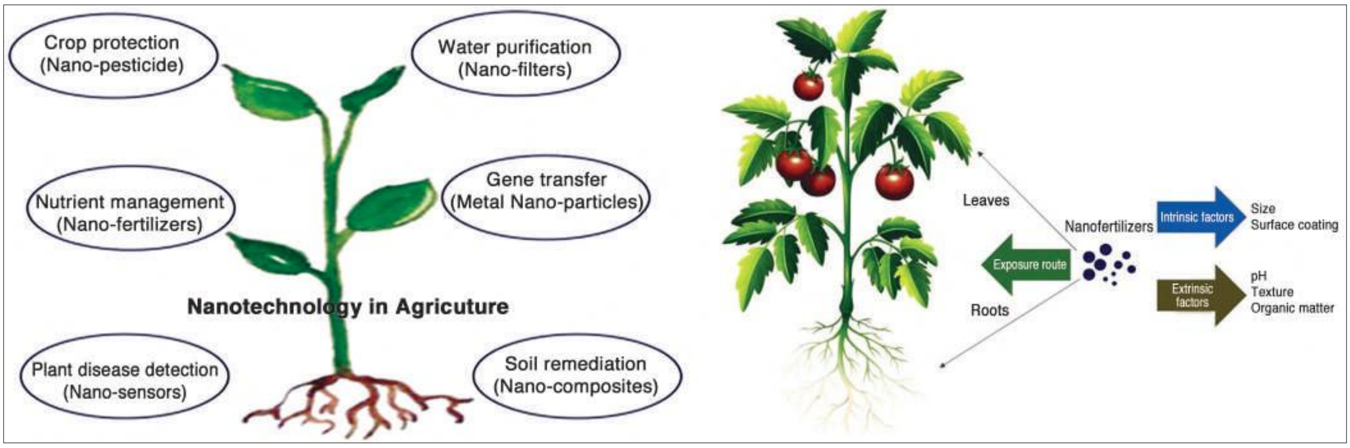
*In recent years, there has been a concern regarding the quantity of mineral fertilizers used in agriculture that adversely affect the environment. Attention has been drawn to the fact that when nutrients are applied to crops, they are not all taken up by the plants immediately. There is also concern that some farmers might be applying inappropriate quantities of fertilizer. The main fertilizers having adverse effects on the environment are nitrate, phosphate and organic matter such as animal manure. In the coming future, there will be increasing pressure on global food systems and Indian agriculture will have the challenge to feed growing population without impacting environment quality. Application of smart fertilizers or rather smart input management is the key to supply sufficient food. Smart fertilization strategy has a great potential to achieve greater crop production and decrease the negative impact on the environment.*

**Keywords:** Biochar, Crop residue, Nutrient Use Efficiency, Smart Fertilization

IMBALANCED nutrient fertilizer application leads to multinutritional deficiency and increases different problems in soil. Nitrogen and phosphorus are essential nutrients for development of plant growth and subsequently high fertilization rates lead to N and P losses with negative impact on atmospheric greenhouse gases concentration and water quality. There is an urgent need to improve Nutrient Use Efficiency (NUE) in Agriculture and manage biochemical cycles in a sustainable way.

The NUE of urea, the major nitrogen fertilizer, currently only averages 30-40% due to its sensitivity to volatilization, denitrification and leaching. The use of slow- and controlled-release fertilizers remains limited. China is by far the largest producer and consumer of smart fertilizers, amounting to one-third of global smart fertilizer (CRF) production. On-field experiments in China have shown 10-40% increase in rice yields with controlled-release fertilizers compared to those with urea. Even when less nitrogen was used, controlled-release fertilizers increased rice yield by 15%. Smart fertilizer use requires 20-30% less nitrogen fertilizer, reducing $CO_2$ emissions for production. Smart fertilizers have lower $N_2O$ emissions during the growing season than common nitrogen fertilizers. Common nitrogen fertilizers lose 1-5% of application as $N_2O$, a greenhouse gas 300 times stronger than $CO_2$. Over the last 150 years, atmospheric $N_2O$ levels have risen 18%, largely due to nitrogen fertilizer use throughout the world. Smart fertilizers have lower $N_2O$ emissions during the growing season than common nitrogen fertilizers. While the cost effectiveness of applying encapsulated controlled release fertilizers in high-value crops is proven, there is also scope for their application to low-value crops.

Total production costs can be reduced by 30% to 50% using smart fertilizers. The controlled supply of nutrients by a single application of a CRF is expected to increase NUE, save labor and/or application costs and improve crop quality and yield. Smart fertilizers are especially beneficial where nutrient loss from conventional fertilizers are high, such as on lightly textured soils with excess rainfall or irrigation. In order to enhance nutrient use efficiency, new types of smart fertilizers with an emphasis on controlled–release and carrier or delivery systems are need. The development of smart fertilizers could also be based on the use of microorganism or bio-fertilizers and nonmaterial (nanofertilizers) thereby reducing nutrient losses. Increased nutrient use efficiency reduced dose of phosphate by half to one fourth and increased yields by 10% thereby farmer income can be raised upto 15-20% . The use of smart fertilizers or rather smart input management should be directed to the economic benefits of Indian farmers for better adaptability. We can then only achieve sustainable agriculture which can feed our next generations to ensure food security and environmental health. In the following article some of new




Nanotechnology in Agriculture. *(Source:* https://www.sciencedirect.com/science/article/abs/pii/S0168945219309021).

fertilizer material are discussed which have potential in this context.

## Synthetic polymers

Synthetic polymers are widely used in agriculture especially for fertilizer development. A broad range of synthetic materials such as petroleum based polymers like polysulfone, polyacrylonitrile, polyvinyl chloride (PVC), polyurethane (PU) and polystyrene are the materials used currently for coating water soluble fertilizers. These polymers are not only safe for environment but also biodegradable and improve water–holding capacity, which in turn enhances nutrient uptake and crop yield. Biodegradable polymers have also been used in bio-formulation acting as microbial carrier for example sodium alginates are widely used for bio formulations (bacterial fertilizers). This bio-formulation is not only environmental friendly but also low cost polymer. Recently, properties of these polymers need to be mixed with synthetic polymers to increase the efficacy of these materials. Triple polymer fertilizer application enhanced the soil water holding capacity thereby enhancing the fertility and productivity. Surface coating on fertilizers with nano materials increased the surface tension resulting in controlled release. Biodegradable polymers protect the microbial inoculants from stress thereby increase the shelf life. It is found that different properties of coating materials can influence the availability of macronutrients (N, P and K) which are present in the core of the coated fertilizers. Different experiments conducted abroad showed that the use of triple polymer fertilizers to encapsulate, enhanced the mechanical properties of different fertilizers like urea. They also suggested that polyethylene in first layer, acrylic acid–co-acryl amide used as super absorbent in second layer and butyl methacrylate in the third layer give good performance in controlled release of urea. Several studies have reported the utilization of these degradable polymers for a wide range of nutrients.

## Nanofertilizers and their types

Nanofertilizers, also called smart fertilizers not only increase nutrient use efficiency but also reduce adverse effects on the environment compared to the use of conventional mineral fertilizers. Nanofertilizers involve the materials at nanoscale level ranging from 1 to 100 nm. There are three main types of nanofertilizers: nanoscale fertilizer (synthesized nanoparticles), nanoscale additives (bulk products with nanoscale additives) and nanoscale coating or host materials (product coated with nanopolymers or loaded with nanoparticles) (Table 1). Slow release nanofertilizers are suitable alternatives to soluble fertilizers. Some nutrients are released at a slower rate during crop growth resulting in reducing their losses. Slow release of nutrients in the environment could be achieved by using Zeolites, also called natural clays, used as a reservoir for nutrients released at slower rate. The nanocomposits, on the other hand, are hybrid materials consisting of a

**Table 1.** Nutrients and their absorbents

| Nutrient | Absorbent | Size (nm) |
|---|---|---|
| Nitrogen (N) | *Zeolite* | 7-10 |
| | | 20-30 |
| | | 87 |
| | | 200 |
| | Montmorillonite | 35-45 |
| | Carbon nanotubes, hydrogels organic Zeolites complexes | 40-80 |
| Phosphorus (P) | *Zeolite* | 25-30 |
| | Montmorillonite, Bentominete and apatite | 35-40 |
| Potassium (K) | Zeolite | 25-30 |
| | Montmorillonite, | 35-40 |
| NPK | Nanocoating of sulphur layer chitosan | 78-100 |
| Nanocomposits | Kaolinite | 30-80 |
| Sulphur (S) | Zeolite | 25-30 |
| Zinc (Zn),Iron (Fe) and | Zeolite | 25-30 |
| Boron (B) | Montmorillonite | 35-40 |
| | Nano Zn and Nano ZnO | 35-20 |
| PGPR microorganism | Gold nanoparticles | - |
| and bimolecular as enzymes | Nanoclays (Allophane) | 100 |

*Source*: Nanotechnologies in Food and Agriculture. Springer, Switzerland, pp. 69–80.

continuous phase or matrix and a dispersed (nanofiller) phase. The dispersion of a small amount (<10%) of nonmaterial in the polymer matrix can lead to marked improvement in both physical and mechanical properties. Recent research is focused to introduce different nanocomposits to supply essential nutrients through smart delivery system. For the first time in India, IFFCO launched nano-tech based fertilizers like nanonitrogen, nanozinc and nanocopper for on-field trials. Listing out other benefits, IFFCO said these nanoproducts help in reduction in the requirement of conventional chemical fertilizer by 50%, raise crop production by 15-30%, improve soil health and cut emission of greenhouse gases. As coating and cementing materials, the nanofertilizers and sub-nanocomposits can also be used to regulate the release of nutrients from the fertilizer capsule. Thus, the future improvement must focus on nanofertilizer which allow nutrient release from nanofertilizers triggered by environmental conditions. In this perspective, nanodevices or additives such as nanotubes, aptamers, double hydroxides, nanocomposits, urease enzymes, nanosize titanium dioxide, and nanosilica particle can be associated to nanofertilizers to synchronize the fertilizer release with plant demand.

### Biostimulants, Biofertilizers and plant growth promoting Rhizobacteria (PGPR)

Biostimulants are natural or synthetic substances that can be applied to seeds, plants, and soil. These substances cause changes in vital and structural processes in order to influence plant growth through improved tolerance to abiotic stresses and increase seed, grain yield and quality. In addition, biostimulants reduce the need for fertilizers. In small concentrations, these substances are efficient, enhancing nutrition efficiency, abiotic stress tolerance, and crop quality traits, regardless of its nutrients content. These substances when applied exogenously have similar actions to the groups of known plant hormones, viz. auxins, gibberellins and cytokinins. In general, biostimulants are produced as a junction of natural or synthetic substances composed of hormones or precursors of plant hormones. When applied correctly in the crops, they act directly on the physiological processes providing potential benefits for growth and development, respond to water and salinity stress, and elements such as toxic aluminum. These products, which differ from traditional nitrogen, phosphorus and potassium fertilizers, may contain in their formula a variety of organic compounds, such as humic acids, seaweed extracts, vitamins, amino acids, ascorbic acid and other chemicals. Major groups of biostimulants are humic substances, protein hydrolysate and amino acid stimulants, seaweed extract and PGPR.

Biofertilizers on the other hand have an indirect effect on the availability of nutrients without itself supplying nutrients. They are live microbial formulations which help in availability and uptake of nutrients. Diazotrophic bacteria are capable of converting atmospheric dinitrogen ($N_2$) into $NH_3$, which can be used by plants. A number of free living soil bacteria are considered to be PGPR because of their competitive advantage in carbon rich and nitrogen poor situations. PGPR associated with root helps in production and regulation of phytohormones, slow release of nutrients (e.g. P and N Fixation) fixed nutrients chelating micronutrients (siderophores among other) produce of antibiotics (phytopathogens) and are anti-pathogenic. Encapsulation microorganism in carrier material (bioformulation) is designated to protect them during storage and from adverse condition, viz. *p*H and temperature. Agri-Life SOM Phytopharma (India) Limited produces Agri Boom (foliar spray), Aminoacid-Gr, Kohinoor as biostimulants and Fe-sol B, Agri-Life Nitrofix as biofertilizers. Materials suitable for immobilization and preservation of bacteria include alginate gels, synthetic gels (Sol-Gel) polyacrlamide agar and agarose, polyurethane vermiculite and polysaccharides.

### Harvested residues as smart fertilizer

Low cost materials like straw are abundantly available resources in current agricultural systems which contain lignin, hemicelluloses and cellulose that impart mechanical strength properties. Wheat straw contains surface carboxyl, hydroxyl, ether, amino and phosphate which increase its reactivity and physiochemical properties, useful in

Crop residue as a fertilizer *(Source:* https://extension.umn.edu/corn-harvest/crop-residue-management)


Biochar (*Source:* https://www.slideshare.net/saibhaskar/biochar-and-soil-environment)

the preparation of absorbent materials for the treatment of waste water and slow release fertilizers. However, straw is susceptible to rapid decomposition in soil. A combination of clay or biochar along with wheat straw can act as release fertilizers. Cellulose obtained from residues has been also used in bioformulation as carrier for bacterial inoculants with broad spectrum antifungal activity and suppression of fungal pathogens. The menace of burning crop residues can be reverted back by using these residues for smart fertilizer. Potential use of wheat straw for the development of slow release N and boron fertilizers with water retention properties has been well known. Lignocelluloses and compost are subject to rapid decomposition once incorporated into soil. In order to further improve their properties as slow release fertilizers, they could be combined with clay minerals or biochar to reduce their decomposition.

### Use of biochar for smart fertilizer

Harvesting residues such as wheat straw may also be used as feedstock for energy producing pyrolysis systems which generate biochar or pyrogenic carbon (biochar). Biochar has been widely used as soil ameliorant and also used to increase C sequestration. Biochar is obtained through pyrolysis of agricultural or other lignocelluloses biomass at temperature ranging from 350°C to 700°C. Biochar was found to increase the C sequestration potential of soil through its high stability. Biochar produced from corncob, banana stalk and pomelo peel displayed an excellent retention ability in holding $NH_4^+$ associated to the presence of carboxyl and keto groups when the material was prepared at 200°C, suggesting that material could be used as slow–release carrier for N. Recent studies have also investigated the use of biochar and charcoal as carriers in combined formulations with beneficial microorganism. Biochar was a useful carrier for different bacterial populations. The use of biochar as carrier for smart fertilizers could be highly beneficial, as it combines nutritional benefits for plants with improvement of many other soil functions due to the addition of biochar itself. In particular, biochar addition to soil has positive effects on water holding capacity as well as C sequestration.

## SUMMARY

In Indian agriculture, there is a lot of technological development taking place. Despite availability of smart fertilizers, their use in agriculture is very limited i.e. less than 1% of the total worldwide fertilizer consumption. Several advantages could be observed in smart fertilizer compared to conventional fertilizer. Smart fertilizers based on slow or controlled-release and carrier delivery system have been shown to improve crop yields, soil productivity and lower nutrient loss compared to conventional fertilizers. Seven materials like clays, monoclays, polymers and harvesting residues are suitable for the development of smart fertilizers by acting as carrier matrices for nutrients and bacterial inoculants. Smart fertilizers would reduce losses of nutrients, prolong fertilizer cycles and enhance effective nutrient uptake by crops. These can substantially decrease the risk of environment pollution. Taking into account these economic aspects and the extremely important environmental aspect, the use of smart fertilizers in Indian agriculture would benefit farmers. Smart fertilizer could be boon for Indian agriculture.

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# Integrated Farming System:

## A boon in hill farming system

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*Integrated Farming System (IFS) has consistently showed potential to provide sustainable income and employment to the farming community. Mrs. Premkit Simik Lepcha, a tribal lady staying in the remote area in the hilly district of West Bengal has shown a way of livelihood through IFS. With the adoption of different components, IFS has helped fetch good income. The B:C ratios of different components have shown promising results and ability for its sustainability. The IFS in hill farming system under study created more than 1685 mandays in a year.*

**Keywords:** Economics, Employment generation, Hill region, IFS

SMALL scale IFS is family farming system through integration of different available components. This is a success story of a tribal lady Mrs. Premkit Simik Lepcha staying in the remote area in the hilly district of Kalimpong in West Bengal where life is not easy. She used to engage in small scale agriculture, horticulture, basically growing vegetables and her main focus was animal husbandry. In the year 2015, she came in contact with Darjeeling Krishi Vigyan Kendra, Kalimpong though a training programme. Learning new techniques in agriculture, horticulture and animal husbandry and then implementing those technologies and ideas were always her passion. Even after implementing many new ideas in her farm, she regularly visited the Krishi Vigyan Kendra of and on. Her IFS is one of the model farms for arranging exposure visit for farmers to showcase the ideal IFS in hill region.

### Small profile of Integrated Farming System

It is a well-known fact that water scarcity is a major hurdle in hill region among majority of the farmers engaged in agriculture. Though Mrs. Lepcha had an area of 3 acre of land for engaging in field crop cultivation and horticulture, it could not be fully utilized with a cropping intensity of 1.7. She also had some area under cardamom cultivation. Due to the problem of irrigation, she focused more on animal husbandry. She had a unit for Pig, Cattle and Poultry. She had purchased 6 months old Hampshire pigs (2 sow +1 boar) initially, which increased to 5 sows + 1 boar for production of piglets. She had 2 dairy cattle and about 120 poultry birds which include Vanaraja, Rhode Island Red and desi poultry birds. She further cultivated vegetables (0.5 acre), large cardamom (1 acre), ginger (1 acre) and turmeric (1 acre) under rainfed agriculture.

### Production practice and Economics of pig unit

She had spent around ₹ 6000 in

Pig unit under IFS

purchasing piglets in the year 2015 and spent around ₹ 50000 in construction of low-cost pigsty. Later, the farm was renovated and extended for accommodation of 5 sows and a boar which further included an additional expenditure of ₹ 1.2 lakhs.

The piglets she had purchased initially became adult at the age of 7-8 months which resulted in breeding. At the age of 13-14 months, the two sows gave birth to piglets with a litter size of 10-12 per sows, and about 44 pigs were added in one year of her pig farm which was a boom in the growth of her pig entrepreneurship.

In the first year (i.e. 2016), 39 piglets (3 piglets died due to cold, mismothering and unknown reasons) were sold out at ₹ 3500 per piglet (male) and ₹ 3000 per piglets (female) after weaning (i.e. 2 months age) and gave 1.27 lakhs within a year. Two piglets were kept for enhancing the breeding stock. In the year 2017-18, she had sold (on an average) about 120 piglets and earned approximately ₹ 3.78 lakhs. It was estimated roughly that the yearly income through small scale pig furrowing (5 sows and 1 boar) was about ₹ 3.97 lakhs, while the net return was about ₹ 2.71 lakhs. Additionally, the waste product of pig unit such as excreta, urine and water used during washing and cleaning were used in the vegetable field.

Cattle unit under IFS

### Production practice and economics of cattle unit

The desi cattle reared for long were crossbred through artificial insemination procedure and thus the dairy unit consisted of 2 cross breed dairy cattle. The feeding was managed with available straw, tree fodder and green grasses under stall feeding practices. The milk production of the two dairy cattle was an average of 4.2 litres per animal per day during peak milk period which had an income of about ₹ 240 daily with total milk production of 860 litres per animal per lactation which earned an income of ₹ 51600 where B:C ratio was 2.62 and rate of return was 1.62 (Table 1). In addition to this, the dung was used as farm yard manure in crop field and the urine and water used during washing and cleaning of shed and utensils were used in the vegetable field.

### Production practice and economics of poultry unit

Vanaraja and Rhode Island Red along with desi birds consisted of the poultry unit under the IFS where around 120 poultry birds were maintained on an average. Low-cost poultry shed were constructed with locally available bamboos and iron net. The birds were allowed for scavenging but sometimes supplemented with poultry feed. The eggs were sold locally and also to the nearby market for around ₹ 8-10 depending on the demand of the eggs in the market. The annual income from poultry birds excluding the expenditure in feed, medicines and cost of chicks was ₹ 85600 where B:C ratio was 3.04 and rate of return was 2.04 (Table 1). The excreta of the poultry birds which is a very good sources of nitrogen was used as compost in the crop field. In addition to this, the poultry birds during scavenging consumed insects from the vegetable field and checked the insect load of the crop and thus reduced crop damage.

### Production practice and economics of horticultural crops under IFS

Livestock units had contributed immensely to the income but it was also seen that horticultural crops had also contributed to the income of the farmers. As the area is rainfed, the crop chosen by the farmers were only

Poultry unit under IFS

Seasonal vegetables grown in the IFS

those which could be grown in rainfed condition. The yield, gross expenditure, gross return, net income with B:C ratio of different crops under IFS are shown in details (Table 2). Moreover, the vegetable wastes cleaned before marketing were used as fodder for livestock and also used in vermicompost.

### Economics of seasonal vegetables crop

Vegetables like cabbage, cauliflower, pea, carrot, leafy vegetables, tomato, spinach beans and coriander leaves were cultivated round the year in a small plot of land. The economic analysis of all the seasonal vegetables in the small plot of land after family consumption is provided in Table 2. The study shows that it provides a net income of ₹ 7570 having B:C ratio of 2.09 and rate of return of 1.09. Additionally, the vegetable wastes which were cleaned before marketing were used as fodder for livestock and some were also used in vermicompost.

### Economics of large cardamom crop

Large cardamom is a high value perennial spice crop. Planting was done in June-July. Pits of 30 cm× 30 cm×30 cm were prepared with a spacing of 1.5 m×1.5 m. The pits were left open for weathering for 15 days, then 3 kg of well decomposed farm yard manure was added to each pit. Seedlings and suckers were planted in the middle of the pit. Organic mulching with dry leaves was done to retain moisture and control weed. The sucker came into bearing stage a year after planting and seedling came into bearing stage 3 years after planting. Sprinkler irrigation equivalent to 35-45 mm of rain at fortnight interval was done. The production of large cardamom was around 5.70 quintals per acre under IFS and gave a net income of ₹ 63122 having B:C ratio of 1.70.

Farm yard manure used in crop fields.

### Economics of ginger crop

Disease free planting materials were procured from the village. 40-50 g of each having one or two buds were taken for sowing in February. At the time of planting, well-decomposed farm yard manure or compost @ 40-50 t/ha, neem cake @ 2 t/ha, biofertilizer (*Azospirillum* + PSB) @ 5-6 kg/ha were applied in rows. It was harvested in the month of November. Rhizomes to be used as planting material were harvested after the leaves became completely dry. IFS shows that it gave a gross income of ₹ 53480 and net income of ₹ 22880 having B:C ratio of 1.75.

**Table 1.** Economic analysis of livestock units under IFS

| Livestock Unit | Nos. | Gross expenditure (₹) | Gross return (₹) | Net income (₹) | B:C ratio | Rate of return |
|---|---|---|---|---|---|---|
| Piggery | 6 | 126200 | 396700 | 271300 | 3.14 | 2.15 |
| Cattle | 2 | 31800 | 83400 | 51600 | 2.62 | 1.62 |
| Poultry | 120 | 41900 | 127500 | 85600 | 3.04 | 2.04 |

Note: B:C ratio= Gross return/ Gross expenditure; Rate of return= Net income/Gross expenditure.

**Table 2.** Economic analysis of horticultural crops under IFS

| Crop | Area (acre) | Yield (quintal/ acre) | Gross expenditure (₹/acre) | Gross return (₹/acre) | Net income (₹/acre) | B:C ratio | Rate of return |
|---|---|---|---|---|---|---|---|
| Vegetables | 0.5 | 4.90 | 6939 | 14509 | 7570 | 2.09 | 1.09 |
| Large cardamom | 1.0 | 5.70 | 90278 | 153400 | 63122 | 1.70 | 0.70 |
| Ginger | 1.0 | 17.80 | 30600 | 53480 | 22880 | 1.75 | 0.75 |
| Turmeric | 0.5 | 8.10 | 13840 | 17842 | 4002 | 1.29 | 0.29 |

Note: B:C ratio= Gross return/Gross expenditure; Rate of return= Net income/ Gross expenditure

Additionally, the harvested plants were used as vermicompost.

### Economics of turmeric crop

Sowing of turmeric was done in March and harvested in December under IFS. The gross income was ₹ 17842 per acre which gave a net income of about ₹ 4002 having B:C ratio 1.29. Moreover, the harvested plants were used as vermicompost.

### Employment generation

The economic analysis of the IFS shows that Mrs. Lepcha created more than 1685 mandays for the family which can be regarded as pretty good in the hill farming system. It is also seen that engagement in small scale IFS which is a whole family approach can be done in hilly region.

## SUMMARY

Sustainable income and consistent employment can be achieved by the farming community by adopting IFS. The economic analysis of different components under IFS in hill farming system has shown considerably superior benefit : cost ratio. Economics of the IFS clearly shows that return was higher in livestock units in comparison to horticultural or agricultural crop. The IFS under study also demonstrated that it had created annual mandays of more than 1685 days.

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# Economic revival of farmwomen

## through broiler farming in Andaman and Nicobar Island

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*Scientific broiler farming is one of the emerging income generating activities for the farmers in Andaman and Nicobar Islands due to growing demand of poultry meat and other poultry products in the Islands. ICAR-Krishi Vigyan Kendra, South Andaman empowered the farmwoman Smt. P Meena of Indira Nagar village, South Andaman in the area of scientific broiler farming from which she earned her decent livelihood. She could increase her net profit by ₹ 60,000 to 6,30,000 per annum by this new venture. Her simplicity touched everyone and her efforts encouraged other farmwomen to become independent and follow her path.*

**Keywords:** Broiler farming, Farmwomen, Poultry

POULTRY farming plays a significant role in the livelihood of rural communities in a developing country like India. It is one of the prospective tools to alleviate poverty and unemployment, protein-energy malnutrition, promote nutrition and food security, afford supplementary income and improve the living standard. Poultry farming can be transformed into one of the most adaptable endeavours by imparting rural farmers with skills and scientific packages and practices of technologies. India ranks 3rd in egg production and 5th in poultry meat production in the world, but the availability of the chicken product is far below the recommended level (10.5 kg poultry meat and 180 eggs/ person/annum). The scenario is still alarmingly low in rural areas. The per capita consumption of eggs and meat is about 69 eggs and 3.4 kg meat per annum in India. In Andaman and Nicobar Island, the poultry production is still at the juvenile stage and needs an immediate boost. As per the 19th census, the total poultry population in Andaman and Nicobar Island is 11,65,363. Due to the growing demand of poultry meat in the Island, promotion of scientific broiler farming is one of the emerging income-generating activity for farmers.

Smt. P. Meena, aged 50 years is a progressive farmwoman from Indira Nagar village of South Andaman, and similar to the other households of the area, she had a backyard poultry (60-70 birds) but had no scientific knowledge of rearing them. The location of Indira Nagar makes it a very suitable area for rearing milch cattle, goats and backyard poultry. Smt. P. Meena was eager to learn scientific ways of animal husbandry,

Broiler farm unit of Smt. P. Meena

Smt. P Meena working in her Broiler farm she has undergone various skill imparting training programs in the areas of scientific broiler farming, backyard poultry farming, dairy farming and value addition of milk at ICAR-Krishi Vigyan Kendra (KVK), South Andaman.

After imbibing various skills, studying and focusing on all the pros and cons of the different poultry and livestock farming, Smt. P. Meena chose poultry farming for her livelihood. Though desi poultry, Vanraja bird is the most sought commodity at market and fetches more price, it needs to be reared for a longer period (more than 5 months). Whereas, the commercial broiler bird can be sold after 35 days and the production and profit is higher per unit area compared to the desi bird. To gain the scientific experience, she initially started farming with just 200 broiler birds per batch during 2011-12 in her backyard with a small temporary shelter. By this, she not only could earn a net profit of ₹ 60,000 during the year 2011-12 but also gained experience in broiler farming, feeding, rearing and health management aspects. This was a boost to pave and expand her farming horizontally.

The tourism industry took a new height in the Island, which invited a huge number of tourists to the Island and this caused heavy influx of collared workers from mainland India. Thus, the total population of the visitors from the mainland outnumbered the Island's population and also tourism increased the purchasing power of the islanders. This, in turn, shifted the preference of the islanders towards animal protein and as poultry has no regional and religious taboo, to satiate the whole population the demand of poultry products were sky-high. Huge demand for poultry meat in the market made her think for further expansion after achieving experience on broiler farming. With the support of her family members (husband and two sons), she established the infrastructure (sheds, feeds and equipments) for the Broiler farming to support rearing of 2100 broiler birds in a single batch (in three sheds) with the assistance and support of ICAR-KVK, South Andaman and Animal Science Division, ICAR-Central Island Agricultural Research Institute (CIARI), Port Blair. Her venture achieved great success and incurred a net profit of ₹ 6,30,000 per annum during 2019-20.

## SUMMARY

A farmwoman became self-reliant and earned a decent livelihood from Broiler farming. It takes a lot of hard work and enthusiasm but it gives back much more. Her simplicity touched everyone and her efforts encouraged other farmwomen of the Island to become independent and follow her path. Several other women of the area were interested to follow her path and take up broiler farming as their main vocation and women from surrounding areas also came to her to get first-hand knowledge and suggestion regarding backyard poultry and broiler farming. In this journey of self-reliance, Smt. P Meena got full extended support in all arenas of Broiler farming and management from the ICAR-KVK, South Andaman as well as Division of Animal Science, ICAR-CIARI, Port Blair.

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# Duckling Production

## —A profitable enterprise for rural youth

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*Duck farming with improved breeds is gaining popularity in rural areas of West Bengal, but availability of good quality duckling is still a hurdle. Assessing the demand for these ducklings, some rural youths have started duckling production through low-cost incubator which seems to be a promising enterprise for them. Duck eggs were hatched and ducklings were maintained at an age of 4 weeks. During that period, the ducklings were provided required brooding and vaccination to reduce the mortality in initial phase. The economic analysis of the entrepreneurship has shown that duckling production has promising potential for providing employment to the rural youth.*

**Keywords:** Brooding, Duckling, Entrepreneurship, Rural youth

THE low-cost incubation and hatching of ducklings is showing a new way of employment generation for the rural youth of the Malda district, West Bengal. With the replacement of the desi duck, natural hatching of duck eggs is greatly reduced. It is a very well-known fact that a good layer is always a bad incubator of eggs. Therefore, to get quality duckling artificial incubation is a must. A few rural youths in coordination with Krishi Vigyan Kendra, Ratua, Department of Animal Resources Development, Govt. of West Bengal and also with the use of different ICT applications have gained knowledge and developed small-scale incubators for hatching of duck eggs. The production practices and economics of small-scale duckling production is discussed here for understanding of this entrepreneurship.

### Procurement of hatchable duck eggs

It has been seen that majority of the rural youth engaged in duckling production were not maintaining parental duck stock for laying of hatchable eggs. Collection of hatchable eggs were made from some nearby duck farms who were mainly producing duck eggs for hatching. The duck eggs were purchased at an amount of ₹ 13-14 per eggs. Eggs up to one week old were procured for hatching.

### Storing of hatchable eggs

The eggs were generaly not strictly maintained at recommended temperature and relative humidity but hatching eggs were stored in a cool and dark room before setting it in incubator.

Rural youth with incubator

### Incubation

Incubation period for duck egg is 28 days which is higher than chicken. Temperature and humidity were maintained as per the required standard for duck egg hatching. Eggs were manually turned at least 4 times a day during incubation. Eggs (1200) were put into the incubator, assuming at least 85-87% of hatching percentage. It was expected to get at least 1020–1050 day-old ducklings.

### Brooding of duck

The brooding period (0-4 weeks) is very crucial for duckling and very high mortality may occur, if care and management is not done properly. About 10 sq m area for 1000 ducklings is essential or 100 sq cm area per duckling is adequate for brooding purpose. A temperature of 29-32°C is

Rural youth engaged in brooding and management

maintained during the first week. It is reduced by about 3°C per week till it reaches 24°C at the end of fourth week. During summer months when temperature is higher than the recommended level, air circulation was increased to reduce the temperature. In winter months, a 60-watt bulb at 1-1.5 m height from the ground level is quite sufficient to maintain the required temperature.

Feed is provided in the trays or sprinkled for encouraging the new born ducklings to pick up feed. *Ad libitum* feed is provided in trough type of feeders from day two. Suitable feeders for ducklings were given with growing age. During the time period of 4 weeks, about 15 q of duck starter is required but about 5 q of duck starter was purchased and rest were managed through feeding of locally available low-cost feed (i.e. rice husk and broken rice). Water in the drinkers were provided judiciously which was sufficient for them to drink and not dip themselves. All possible care and management was made to keep the duckling dry.

The ducklings were vaccinated against duck plague at an age of 2-3 weeks with duck plague vaccination available from Govt. sources through paravet workers or sometime purchase from the local market. About 1020-1050 ducklings were brooded in anticipation to get at least 1000 ducklings for marketing if the mortality can be managed at about 3-4% only.

**Table 1.** Economic analysis of hatching and brooding for duckling production

| | Particulars | Amount (₹) |
|---|---|---|
| Gross expenditure (GE) | Eggs procurement cost (@ ₹ 14.00) | 16,800.00 |
| | Incubation cost | 2,200.00 |
| | Vaccination cost | 1,250.00 |
| | Feeding and management | 23,000.00 |
| | Labour cost | 0.00 |
| | Misc. cost | 1,500.00 |
| | Total | 47,750.00 |
| Gross income (GI) | @ ₹ 65.00 duckling (4 weeks of age) | 65,000.00 |
| Net income (NI) | GI-GE | 20,250.00 |
| B:C ratio | GI/GE | 1.45 |
| Rate of return | NI/GE | 0.45 |
| Annual income | NI × 8 batches | 1,62,000.00 |

## Marketing of duckling

Marketing of duckling is a very important aspect for sustainability of the enterprise and like every enterprise there also lies the hurdle of marketing of ducklings at a good price. The ducklings were generally marketed after the brooding period is over. The market rate of duckling varies depending on the age of duckling. On an average duckling at the age of 4 weeks were sold in between ₹ 60-70 per birds.

## Economics

The economic analysis based on hatching of 1200 duck eggs at a time may lead to 1000 duckling production for marketing after the brooding period is over. The brooding and management of ducklings during early period of up to 4 weeks would reduce the mortality. The ducklings were sold only after brooding period to reduce mortality. If the hatchable eggs were timely available and the duckling could be marketed in time, then at least 8 batches of such duckling production and brooding of eggs could be done. Analysis of hatching and brooding per batches of 1000 ducklings is given in Table 1. The labour cost was nil as family labour was utilised in the enterprise. Therefore, it can be said that the enterprise may give an annual income of ₹ 1.62 lakh with a monthly income of more than ₹ 13500.

## SUMMARY

Entrepreneurship development through duckling production with low-cost incubator is a promising enterprise that can be a good source of income for the unemployed rural youth. Economic analysis has shown that the enterprise has the potential to provide year-round employment to the rural youth with good remuneration if proper care and management during incubation and brooding of ducklings is done.

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# Organic Farming:
## An approach for sustainable agriculture

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*Organic farming is a sustainable agriculture production system being followed since ancient times in India. The natural resource management and biodiversity conservation are core principles of organic agriculture. During post independence era, the most important challenge was to produce enough food grain for the growing population. Hence, high-yielding production system with chemical fertilizers and agrochemicals was adopted. The system has concerns related to soil health, agrosphere, environmental pollution, sustainability and productivity. Organic farming is a system of farming that involves growing and nurturing crops without the use of synthetic fertilizers and pesticides. Also, no genetically modified organisms are permitted. The primary aim of organic farming is to keep the soil in good health through the use of biological materials along with beneficial microbes to release macro and micronutrients to crops for increased sustainable production in an ecofriendly, pollution free environment. Organic farming provides quality food and is beneficial to human health and environment.*

**Keywords:** Climate change, Cost-benefit analysis, Organic farming, Sustainable Agriculture

ORGANIC farming is an alternative agricultural system which originated early in the 20th century in reaction to rapidly changing farming practices. Commercial organic agriculture is now being practiced in more than 170 countries, and is gaining gradual momentum across the world. Highest number of organic producers are in Asia (36%) followed by Africa (29%) and Europe (17%). There is 43.1 Mha of organic agricultural land in India including conversion areas with 2 million producers. Organic farming management is an integrated approach, where all aspects of farming system are interlinked with each other and work for each other. A healthy biologically active soil is vital for crop nutrition; on-farm biodiversity controls pests, crop rotation and multiple cropping maintains the system's health, and on-farm resource management with integration of cattle ensures productivity and sustainability. According to FAO "Organic agriculture is a unique production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity, and this is accomplished by using on-farm agronomic, biological and mechanical methods in exclusion of all synthetic off-farm inputs". Organic farming leads to production of high quality food in sufficient quantity in harmony with natural systems and cycles. This system makes use of organic wastes, and crops are raised in such a manner that it keeps the soil healthy and alive. Microbes are used as bio-fertilizers to increase production without polluting the environment. The key characteristics include protecting the long-term fertility of soil by maintaining organic matter levels, fostering soil biological activity, careful mechanical intervention, nitrogen self-sufficiency through the use of legumes and biological nitrogen fixation, effective recycling of organic materials including crop residues and livestock wastes and weed, and diseases and pest control relying primarily on crop rotations, natural predators, diversity, organic manuring, and resistant varieties. A great emphasis is placed to maintain the soil fertility by returning all the wastes to it chiefly through compost to minimize the gap between NPK addition and removal from the soil. The key factors affecting consumer demand for organic food is health consciousness and willingness of the public to pay for the high-priced produce. Government policies aim to stimulate the organic sector through subsidies, consumer education, and support in the form of research, education, and marketing.

Agricultural practices of India date back to more than 4000 years, and organic farming is very much native to this country. As mentioned in *Arthashastra*, farmers in the *Vedic* period possessed a fair knowledge of soil fertility, seed selection, plant protection, sowing seasons, and sustainability of crops. After almost a century of development organic agriculture is now being embraced by the mainstream, and shows great promise commercially, socially and environmentally. While there is continuum of thought from earlier days to the present, the modern organic movement is radically different from its original form. It now has environmental sustainability at its core in addition to concerns for healthy soil, healthy food and healthy people.

Organic nutrition garden

## Prospects

India has traditionally been a country of organic agriculture, but the growth of modern scientific, input intensive agriculture has pushed it to wall. With the increasing awareness about the safety and quality of food, long term sustainability of the organic farming system and evidences of being equally productive, organic farming has emerged as an alternative system of farming which not only addresses the quality and sustainability concerns, but also ensures a debt free, profitable livelihood option. Commercial organic agriculture with its rigorous quality assurance system is a new market controlled, consumer-centric agriculture system. During the last 10 years, it has grown at pace of 25-30% per year, world over. Even though the above factors have contributed to the growth of market for organic food, it is interesting to note that there have been no major promotion campaigns in catering organic food. In this context, marketing concepts need to be prominent but cannot dominate totally. The key factor affecting consumer demand for organic food is the health consciousness and the willingness of the public to pay for the high-priced produce. India is poised for faster growth with growing domestic market. Success of organic movement in India depends upon the growth of its own domestic markets. The concept of organic farming has strong marketing appeal, growth forecasts are almost all positive and it has been suggested that the 'movement' is now an 'industry'. Organic agriculture is one of the fastest growing agribusiness sectors in the world, with double-digit annual growth in land under organic cultivation, value of organic produce and number of organic farmers. There is about 26 Mha organic farmland currently. National Programme on Organic Production (NPOP) defined its regulatory framework; the National Project on Organic Farming (NPOF) has defined the promotion strategy and provided necessary support for area expansion under certified organic farming. Initial estimates during 2003-04 suggested that approximately 42,000 ha of cultivated land was certified organic. By 2012, India had brought more than 11.2 Mha of land under certification. India has also achieved the status of single largest country in terms of total area under certified organic wild harvest collection.

## Constraints

**Land:** Out of total geographical area of India (328.7 Mha), about 80% (264.5 Mha) is under agriculture, forestry, pasture and biomass production. India supports approximately 16% of the world's human population and 20% of the world's livestock population on merely 2.5% of the world's geographical area. The steady growth of human population coupled with fastpaced developmental activities exerts heavy pressure on India's limited land resource and causes severe land degradation. According to latest estimates, about 184.8 Mha of land (57% of total land area) has been degraded due to various reasons. Groundwater depletion occurs in regions intensively irrigated by tube wells. The rate of loss of soil organic carbon (SOC) and total nitrogen (TN) in surface soil horizon decreases with cultivation. Over 10.9 Mha of permanent pasture contains 42 animals per hectare for grazing against the threshold level of 5 animals per hectare. Overgrazing and massive extraction of fodder increase compaction and reduce infiltration ultimately changing the soil quality. Most parts around urban and industrial areas are witnessing massive release of solid and liquid waste. In addition, India is witnessing open cast mining in many of its geographical regions with consequent increase in soil *p*H, Mg : Ca ratio, bulk density, clay dispersibility, total magnesium and calcium carbonate and decrease in soil porosity and available phosphorous.

**Water quality:** According to the National Water Quality Inventor report, compared to the point sources, agricultural non-point sources (NPS) are the leading contributor to water quality degradation of rivers and lakes. Agricultural activities as non-point source of pollution include sedimentation, eutrophication, salinization through irrigation in arid areas and addition of pesticides and heavy metals to streams, lakes and rivers through runoff. Further, the quantity of fertilizer use, type of farming practices and crop species also affect the groundwater quality. In comparion, nutrient loss to run-off is considerably low from organic farm lands.

**Irrigation:** Industrial and municipal waste waters containing toxic metals such as Zn, Cu, Pb, Mn, Ni, Cr, Cd are increasingly being used for irrigating crops especially in urban and peri-urban areas of developing countries due to easy availability, disposal problems and scarcity of unpolluted fresh waters. Regular irrigation of cropland with sewage and industrial wastewater may cause heavy metal accumulation in soil, degrading soil quality. Plants irrigated with wastewater accumulated 116–378 mg/kg Fe, 12–69 mg/kg Mn, 5.2–16.8 mg/kg Cu and 22–46 mg/kg Zn. In a study at Varanasi, continuous application of treated wastewater was found to cause accumulation of Cd (1.55-13.80 µg/g), Pb and Ni (10.45-39.25 µg/g) exceeding their safe limits for heavy metal contamination of Ganges, the major river system of north India.

**Atmospheric deposition:** Atmospheric deposition of pollutant aerosols is rising in many parts of the world including India. Atmospheric deposition of toxic metals could affect human health and plant performance directly or through soil and food chain associated routes. Deposition of heavy metals not only leads to multifold accumulation in tomato, eggplant, spinach, amaranthus, carrot and radish but also cause significant damage to soil microbial activity in organically amended soil. Thus, deposition of heavy metals may compromise organic farming's ability of stabilizing soil fertility and providing toxin-free produce.

**Livestock resources:** Livestock resources have played multifaceted roles strengthening indigenous agricultural practices and generating income and livelihoods for large masses of rural dwellers in India. However, with the advent of technology in agriculture, livestock population in our country is rapidly declining. Advent of technology in agriculture coupled with inadequate feed supply is the major determinant reducing attraction of common people towards livestock production, and thus the availability of manure even to small farm. The area under natural pasture in India is rapidly declining as a result of expanding urban and agricultural areas. For maintaining soil fertility and meeting crop nutrient demands, large quantity of organic supplements are needed and accordingly, appropriate farmscale management strategies considering cultural and socio-economic environment of farmholders are required. In particular, lack of sufficient amount of vermicompost and non-availability of biofertilizers in local market further constrain organic producers. In India, most of the crop residues are removed from the fields for use as fodder and fuel. Thus, adoption of mulch farming technique as a potential tool to conserve soil organic matter content to sustain biomass/ agronomic yield is possible if cost effective alternate sources of fodder and fuel are identified and made available at large scale.

**Certification:** Access to certification, cost involved and a time lag of three years (conversion stage) often constrain farmers especially small land holders in India from adopting organic farming. Organic produce needs certification to ensure that all synthetic inputs are prohibited and soil building approaches are followed. The certification process aims at converting the growing area to comply with requirements of standard within a period of three years. For this reason, farmers who adopt organic management need to wait for up to three years under certification procedures that requires purging of chemical residues. In India, the Director General of Foreign Trade, New Delhi, permits the export of organic produce provided that these are produced, processed and packed under a valid organic certificate issued by a certification agency accredited by an accreditation agency designated by the Government of India. The Government of India has recognized Tamil Nadu Organic Certification Department, Agricultural and Processed Food Products Export Development Authority (APEDA), Spice Board, Ministry of Commerce and Industry, Coffee Board and Tea Board for the purpose. However, lack of knowledge, rationale capital and access to certification discourage small holders in developing countries including India. There may be a deficit in net income under organic farming compared to conventional one up to third year. As input cost declines, the net income increases progressively fourth year onward. However, the initial three year deficit coupled with certification associated constraints often make small holders apprehensive.

## Opportunities

A substantial amount of $CO_2$ comes from soil through decomposition, mineralization and soil respiration. Conventional agricultural practices that most often accelerate these processes can substantially influence atmospheric C balance on global scale. The mechanism and potential of C-sequestration in converted ecosystems are still not well understood and probably for this reason, predictions made for global carbon balance remain uncertain. The soil C pool reflects a balance between the input and output, and if the carbon flux is low relative to storage it leads to sequestration in soil but a higher flux causes C loss. Soil carbon sequestration holds the greatest global C mitigation potential. Most agricultural soils have lost 30–70% of their antecedent SOC pool. Soil carbon sequestration is cost effective and may contribute to about 89% of total C mitigation. India, representing almost all major climatic zones and wide range of land use systems, has vast opportunities for soil carbon sequestration. Conversion from natural to agricultural ecosystem causes depletion of SOC pool by 60% in soils of temperate regions and over 75% in cultivated soils. Since the soil

C can have a stable and long residence time, even hundreds to thousands of years under many circumstances, the conversion of plant sequestered C to soil organic C could play a crucial role. The major determinants regulating C-flux or storage in soil include climate (especially temperature), soil moisture, microbial biomass and quantity and quality of natural and added organic inputs. Although the major goal of any agricultural practice is to enhance crop yield, recent global attention has focus to link agricultural management strategies with C–sequestration and sustainability of agro-ecosystems. Sequestration of C may be in the form of soil organic carbon (SOC) and soil inorganic carbon (SIC). Common recommended management practices (RMPs) include mulch farming, conservation tillage, agro-forestry, diverse and intercropping systems, crop rotation, cover crops, and integrated nutrient management including the use of manure, compost, bio solids, improved grazing, and forest management. Further, many agricultural activities enhance GHG emissions. Rice is an important crop in India constituting over 42.5% of the area under cereal cultivation. Rice is cultivated under flooded condition and the anaerobic condition created during rice cultivation leads to emission of $CH_4$ and $N_2O$. A recent study conducted in Punjab indicated that organic amendment can significantly reduce methane emission from rice field.

Employment opportunities is one of the major issues of developing countries. Organic, farming requires over 15% more labour than traditional farming and therefore provides rural job opportunities. Some of the commonly used organic farming techniques such as strip farming, non-chemical weeding, and production, collection and transportation of organic supplements all requires significant labour. The labour scarcity and cost involved therein, may constrain adoption of organic farming in developed countries and also for cash-poor farmers in developing countries. However, for countries like India, labour as well as the cost involved therein is not a constraint. Instead, organic farming can generate employment opportunity for a vast section of rural communities.

## Strategies

A live, healthy soil with proper cropping patterns, crop residue management and effective crop rotation can sustain optimum productivity over the years, without any loss in fertility. A living soil can be maintained by continuous incorporation of crop and weed biomass, use of animal dung, urine-based manures (FYM, NADEP, vermicompost), biofertilisers and bio enhancers, special liquid formulations (like vermin wash, compost tea etc.). Important components of organic farming are crop rotation, use of crop residue, biological nitrogen fixation, biopesticides, biogas slurry etc.

### *Multiple cropping and crop rotation*

For practicing sustainable agriculture there should be rotation of crops on the same land over a period of two years or more for maintaining soil fertility, and control insects, weed and diseases. Mix cropping is the outstanding feature of organic farming in which variety of crops are grown simultaneously or at different time on the same land. In every season care should be taken to maintain legume cropping at least 40%. Mix cropping promotes photosynthesis and reduces the competition for nutrients because different plants draw their nutrients from different depth of soil. The legumes fix atmospheric nitrogen and make it available for companion or succeeding crops. Deep rooted plants draw nutrients from deeper layer of soil and bring them to the surface of soil through their leaf fall. All high nutrient demanding crops should precede and follow legume dominated crop combination. Rotation of pest host and non pest host crops helps in controlling soil borne diseases and pests. It also helps in controlling weeds. Crop rotation is the backbone of organic farming practices. To keep the soil healthy and to allow working of natural microbial systems, crop rotation is a must.

### *Manuring and soil enrichment*

India has a great potential of using residues of crops and straw of cereals and pulses for recycling nutrients in organic farming. Crop residues when inoculated with fungal species improve physicochemical properties of soil and crop yields. During conversion period, soil fertility can be improved and maintained initially through use of organic inputs like well decomposed organic manure/ vermicompost, green manure and biofertilizers in appropriate quantity. Plant biomass, FYM, cattle dung manure, enriched compost, bio dynamic compost, cow-pat-pit compost are key sources of on-farm inputs. Among off-farm inputs, important components are non-edible oil cakes, poultry manure, biofertilizers, mineral grade rock phosphate and lime etc.

**Organic manure:** It is obtained from biological sources (plant, animal and human residues). Organic manure helps in increasing crop growth directly by improving the uptake of humic substances and indirectly by promoting soil productivity by increasing availability of major and minor plant nutrients through soil microorganisms.

Bulky organic manure includes compost, FYM and green manure having less nutrients in comparison to concentrated organic manure. Large quantities of waste material (vegetable refuse, weeds, stubble, straw, sugarcane trash, sewage, sludge, animal waste, human and industrial refuse) can be converted into compost by an aerobic decomposition. Farm Yard Manure (FYM) refers to the well decomposed combination of dung, urine, farm litter and leftover materials (roughages or fodder). Green manuring is the practice of adding organic matter to the soil by incorporating undecomposed green plant tissues for improving soil health. The green manure crop (legumes) supplies organic matter and additional nitrogen. Commonly used green manure crops are sunhemp (*Crotalaria juncea*), dhaincha (*Sesbania aculeata*), cowpea, cluster bean, senji (*Melilotus parviflora, Vigna sinensis*), berseem

(*Trifolium alexandrium*) etc.

**Vermicompost:** Vermicompost is organic manure or compost produced by the use of earthworms that generally live in soil, eat organic matter and excrete it in digested form. It is rich in macro and micronutrients, growth hormones and immobilized micro flora essential for plant growth.

**Concentrated organic manure**: Oilcakes, blood meal, fishmeal, meat meal, and horn and hoof meal are organic in nature. These are made from raw materials of animal or plant origin, and contain higher percentage of vital plant nutrients as compared to bulky organic manures.

**Biofertilizers:** Biofertilizers are microorganisms that have the capability of increasing the fertility of soil by fixing atmospheric nitrogen and phosphate solubilization. Biofertilizers, viz. *Rhizobium, Azotobacter, Azospirillum,* PSB and *Pseudomonas* etc. have been found to be very effective tools of fertility management and biological nutrient mobilization. Recently, customized consortia of such biofertilizer organisms, better adapted to local climatic conditions have also been developed and are available commercially. Efficiency of such microbial formulations is much higher under no-chemical use situations, therefore, application of such inputs needs to be ensured under all cropping situations. Some important and widely used bio-fertilizers are given here.

*Rhizobium, Frankia* and *Anabaena azollae* fix atmospheric nitrogen in roots of leguminous plants, form tumour like growth known as root nodules. These are widely used biofertilizers which can fix around 100-300 kg N/ha in one crop season. Blue Green Algae, *Azolla, Azotobacter, Azospirillium, Beijerinkia, Clostridium, Klebsiella, Anabaena* and *Nostoc* grow on decomposing soil organic matter and fix atmospheric nitrogen in suitable soil medium. *Azotobactor* has beneficial effect on vegetables, millets, cereals, sugarcane and cotton. *Azospirillium* has beneficial effect on oats, barley, maize, sorghum, forage crop and pearl millet. It fixes nitrogen by colonising root zones. *Bacillus megaterium* var. *phosphaticum, Bacillus subtilis, Bacillus circulans* and *Pseudomonas striata* are beneficial bacteria capable of solubilizing inorganic phosphorus from insoluble compounds. Phosphorus solubilization ability of rhizosphere microorganisms is considered important in plant phosphate nutrition. Fungi like *Penicillium, Aspergillus awamori* and *Fusarium* play a noteworthy role in increasing the bioavailability of soil phosphates for plant nutrition.

Arbuscular mycorrhiza *like Glomus* sp., *Gigaspora* sp., *Acaulospora* sp., *Scutellospora* sp. and *Sclerocystis* sp., *Ericoid mycorrhizae-Pezizellaericae,* Ectomycorrhiza-*Laccaria* sp., *Pisolithus* sp., *Boletus* sp., *Amanita* sp. and Orchid mycorrhiza-*Rhizoctonia solani* are phosphate solubilizing microorganisms (PSM) that can play an important role in phosphorus nutrition in many natural and agro-ecosystems. Silicate and zinc solubilizers like *Bacillus* sp. along with recommended dose of major nutrients increases the availability of the essential nutrients in the rhizosphere zone.

*Pseudomonas fluorescens* is known to enhance plant growth and reduce severity of various diseases. The efficacy of bacterial antagonists in controlling fungal diseases was often better as alone, and sometimes in combination with fungicides.

Blue-green algae reduce soil alkalinity and it is good for rice cultivation and bio-reclamation of land.

The process of preparing various cow dung, cow urine filtrates has been described here. These filtrates enrich the soil.

**Beejamruta:** Put 5 kg fresh cow dung in a cloth bag and suspend in a container filled with water to extract the soluble ingredients of dung. Suspend 50 g lime in 1 litre water separately. After 12–16 hours squeeze the bag to collect extract and add 5 lit cow urine, 50 g virgin forest soil, lime water and 20 litre water. Incubate for 8-12 hours. Filter the contents and use the filtrate for seed treatment.

**Sanjivak:** Mix 100 kg cow dung, 100 litre cow urine and 500 g jaggary in 300 litre of water in a 500 litre closed drum. Ferment for 10 days. Dilute with 20 times water and sprinkle in one acre either as soil spray or along with irrigation water.

**Jivamrut:** Mix cow dung 10 kg, cow urine 10 litre, Jaggary 2 kg, any pulse grain flour 2 kg and live forest soil 1 kg in 200 litre water. Ferment for 5 to 7 days. Stir the solution regularly three times a day. Use in one acre with irrigation water.

**Amritpani:** Mix 10 kg cow dung with 500 g honey and mix thoroughly to make a creamy paste. Add 250 g of cow desi ghee and mix at high speed. Dilute with 200 litre water and sprinkle this suspension in one acre over soil or with irrigation water. Apply second dose after 30 days in between the row of plants or through irrigation water.

**Panchgavya:** Mix fresh cow dung 5 kg, cow urine 3 litre, cow milk 2 litre, curd 2 litre, cow butter oil 1 kg and ferment for 7 days with twice stirring per day. Dilute 3 litre of Panchgavya in 100 litre water and spray over soil. About 20 litre panchgavya is needed per acre for soil application along with irrigation water.

**Enriched Panchgavya (or Dashagavya):** Ingredients - cow dung 5 kg, cow urine 3 litre, cow milk 2 litre, curd 2 litre, cow deshi ghee 1 kg, sugarcane juice 3 litre, tender coconut water 3 litre, banana paste of 12 fruits and toddy or grape juice 2 litre. Mix cow dung and ghee in a container and ferment for 3 days with intermittent stirring. Add rest of the ingredients on the fourth day and ferment for 15 days with stirring twice daily. The formulation will be ready in 18 days. Sugarcane juice can be replaced with 500 jaggery in 3 litre water. In case of non-availability of toddy or grape juice 100 g yeast powder mixed with 100 g jaggery and 2 litre of warm water can also be used. For foliar spray 3-4 litre panchgavya is diluted with 100 litre water. For soil application 50 litre panchagavya is sufficient for one ha. It can also be used for seed treatment.

*Weed management*

Weed growth is blocked using plastic films and the process is known as mulching. Mowing and cutting removes the top growth of weeds. Grazing is another method which helps in reducing weed growth. Organic farmers integrate cultural, biological, mechanical, physical and chemical tactics to manage weeds without synthetic herbicides. Organic standards require rotation of annual crops, meaning that a single crop cannot be grown in the same location without a different, intervening crop.

*Pest management*

In organic farming use of synthetic chemicals is prohibited, rather the pest management is done by: (i) cultural or agronomic (ii) mechanical (iii) biological or by (iv) organically acceptable botanical extract or some chemicals such as copper sulphate and soft soap etc.

**Cultural alternative:** Use of disease free seed or stock and resistant varieties are best preventive practices in organic pest management. Maintenance of biodiversity, effective crop rotation, multiple cropping, habitat manipulation and use of trap crops are also effective practices which can keep the population of pests below economical threshold limit (ETL). In the border of the main crop, different natural enemy attracting crops like marigold/other yellow colored flowers ornamental crops, should be planted and synchronized with the main crop. The crop like coriander in gram, mustard, can also be planted in order to promote and conserve the natural enemies. Proper plant spacing and alley planting of the crops should be done with a proper gap between rows and plants. After every 2-3 meter plantings of the main crop a gap of 0.75-1.00 meter should be practiced.

**Mechanical alternative:** Removal of affected plants and plant parts, collection and destruction of egg masses and larvae, installation of bird perches, light traps, sticky coloured plates and pheromone traps are most effective mechanical methods of pest control (Table 1). Light trap is for all nocturnal flying insects: 1 trap/ha (60 watt CFL). Sticky trap yellow is for the monitoring of aphid, jassid, like insects. 1 trap/100 $m^2$ area. Sticky trap blue is for the monitoring of thrips like insects. 1 trap/100 $m^2$ area. Votta T trap is used for Brinjal shoot and fruit borer, Pin moth. For the monitoring 10 traps/ha and for the management 25 traps/ha are used. Pheromone trap is a general tool which is mostly used for lepidopteran insects, it causes damage at larval stages. For the management of adult stage of different species of Lepidoptera insect sex pheromones available in the market can be used.

Table 1. Management of Pests by Mechanical methods

| Insect | Lure | Crop | Time of installation |
|---|---|---|---|
| Rice stem borer | Scirpo | Rice | One week after transplanting. End of tillering stage |
| *Helicoverpa armigera* | Helli | Gram and different crop | 25 days after sowing. At flower initiation. |
| *Spodoptera litura* | Spodo | Different crops | One week after transplanting. Three weeks after sowing. |
| Spotted bollworm | Ervit | Okra and Cucurbitaceous crops | One week after transplanting. One week prior to flowering. |
| Diamondback moth | DBM | Cole crops | One week after transplanting. |
| Brinjal Shoot and fruit borer | Leucin | Brinjal | One week after transplanting. One week prior to flowering. |
| Fruit fly | Bador | Mango, Guava, Litchi | Prior to flowering. |
| Melon fly | Baku | Cucurbitaceous crop | One week prior to flowering. |

**Biological alternative:** Use of pest predators and pathogens has also proved to be an effective method of keeping pest problem below ETL. Inundative release of *Trichogramma* sp. @ 40,000 to 50,000 eggs per/ha, *Chelonus blackburni* @ 15,000 to 20, 000 per ha, *Apanteles* sp.@15,000 to 20,000 per ha and *Chrysoperla* sp.@ 5,000 per ha, after 15 days of sowing and other parasites and predators after 30 days of sowing, can also effectively control pest problem in organic farming .

**Bio-pesticide:** Biopesticides are of plant origin and include plant products like alkaloids, phenolics, terpenoids and some secondary chemicals. They are biologically active against insects, fungi, nematodes affecting their behavior and physiology. Commonly known insecticides are Pyrethrum, Nicotine, Neem, Margosa, Rotenone etc. *Trichoderma virideae* or *T. harazianum* or *Pseudomonas fluorescence* formulation @ 4 g/kg seed either alone or in combination, manage most of the seed borne and soil borne diseases. There are other formulations viz. *Beauvaria bassiana*, *Metarhizium anisopliae*, *Verticillium* sp. which are available in the market and can manage their specific host pest. *Bacillus thuringiensis tenebrionis* and *Bacillus thuringiensis sandigo* are effective against coleopterans as well as some other insect species (Table 2). Bt has been used in the management of diamondback moth on crucifers and vegetables @0.5-1.0 kg/ha. Viral biopesticides of baculovirus group, viz. granulosis viruses (GV) and nuclearpolyhedrosis viruses provided a great scope in plant protection field. Spray of nuclear polyhedrosis viruses (NPV) of *Helicoverpa armigera* (H) or *Spodoptera litura* (S) @250 larval equivalents are very effective tools to manage the *Helicoverpa* sp. or *Spodoptera* sp. respectively. *Verticillium lecanii* powder ($10^7$cfu/gram) 2.5 kg should be dissolved in 500 lit of water for per hectare and should be sprayed. As liquid ($10^{10}$-$10^{12}$ cfu/ml) 1000-1250 ml should be dissolved in 500 lit of water and then sprayed for the management of mites and insects like green hopper, leaf miner, thrips, whitefly, brown hopper and other insects. *Beauveria bassiana* powder ($1\times10^8$ cfu/g) 2.5 kg should be dissolved in 500 lit of water for per hectare and should be sprayed. As liquid ($1\times10^{10}$-$1\times10^{12}$ cfu/ml) 1000-1250 ml should be dissolved in

Table 2. Management of pests and weeds through biological agents

| Crop | Major pest | Eco-friendly management through biological agents |
|---|---|---|
| Chickpea/ Pigeon Pea/Lathyrus | *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae) | Application of *Bacillus thuringiensis* Kurstaki 8L @ 1.6 kg per ha. and *Bacillus thuringiensis* Kurstaki ES @ 1.5 lt per ha, respectively, at early stages of crop infestation ($1^{st}$, $2^{nd}$ and $3^{rd}$ instar larval infestation) with at least 2 applications at 7 days interval. |
| Mustard/ Safflower | Aphids (*Lipaphis erysimi*) | *Cheilomenes sexmaculata* Fabricius 5000 larvae or 500 adults per ha, *Coccinella septempunctata.* 5000 larvae or 500 adults per ha. Two releases: first release to coincide with the appearance of aphids. |
| Sunflower | Aphid (*Lipaphis erysimi*). | *Chrysoperla carnea* (Stephens) 10,000 first instar larvae per ha. |
| Brinjal | Fruit and shoot borer (*Leucinodes orbonalis)* | *Bacillus thuringiensis* 500 g ai per ha (10 days interval). 3-4 releases of egg parasite, *T. chilonis* @1.0 lakh per ha |
| Cucurbitaceous | Fruitfly (*Bactrocera cucurbitae*) | Poison bait: Mix Ethyl alcohol-60 ml + Methyl eugenol-40 ml + Malathion/ DDVP (Pesticide)- 20 ml (*i.e.* in the ratio of 6:4:2). |
| | Aphids(*Lipaphis erysimi*) | *Cheilomenes sexmaculata* Fabricius 5000 larvae or 500 adults per ha, |
| Okra | Shoot and fruit borer (*Earias vittella*) Fruit borer (*H. armigera*) | *Trichogramma brassiliensis* 2,50,000 parasitized eggs per ha (Inundative release), 50,000 parasitized eggs per ha (Weekly inoculative release), *Bacillus thuringiensis* 500 g ai per ha (10 days interval) |
| | Okra aphid | *Chrysoperla zastrowi arabica* 50,000 first instar larvae/ha (weekly release) |
| Tomato | Fruit borer *(Helicoverpa armigera*) | *Trichogramma brassiliensis* 2,50,000 parasitized eggs per ha (Inundative release), 50,000 parasitized eggs per ha (Weekly inoculative release), *Bacillus thuringiensis* 500 g ai per ha (10 days interval), HaNPV @ 250 lt per ha (10 days interval) |
| Onion | Thrips | *Xylocoris, Blaptostethus* |
| Potato | Potato tuber moth *(Phthorimaea operculella)* | *Chelonus blackburnii* 50,000 adults per ha in the field. Two releases at weekly intervals. 2 adults per kg of potatoes in godowns. |
| Colocasia | Armyworm *Spodoptera litura* (Fabricius) | *Trichogramma* spp. |
| Cabbage | DBM (*Plutella xylostella*) | *Bacillus thuringiensis* 500 g ai per ha (10 days interval). |
| | Cabbage aphid | *Chrysoperla zastrowi arabica* 50,000 first instar larvae/ha (weekly release). |
| Weeds | Congress grass weed *(Parthenium hysterophorus* L.*)* | *Zygogramma bicolorata* Pallister, one adult was found to bring defoliation of a single parthenium plant in 6-8 weeks. Therefore, if releases are to be carried out at this rate, about 0.4. to 0.7 million insects will be required per hectare, as the weed density varies between 40 to 70 plants per square metre. In practice, it is neither possible nor necessary to release so many insects as they are capable of multiplying rapidly. Releases of about 500-1000 beetles can bring about establishment and eventual control. |

500 lit of water for per hectare and then sprayed. For the areas affected by white grubs mainly for the crop the citrus, mango and coconuts etc. 5 ml of *Beauveria bassiana* per lit water must be applied. *Beauveria bassiana* @ 2 kg should be mixed with 200 lit water dispensed through the drip or drench system to control the grubs. It can be applied on the crops like banana, soybean, paddy, oilseeds, tomato, chilli, potato, maize, sugarcane, turmeric, citrus crop, onion, garlic, floriculture and horticulture crops.

**Botanical pesticides:** Many plants are known to have pesticidal properties and the extract can be used in the management of pests. Among various plants identified for the purpose, neem has been found to be most effective. Neem has been found to be effective in the management of approximately 200 insects, pests and nematodes. Neem extracts are very effective against grasshoppers, leaf hoppers, leaf minor, plant hoppers, aphids, cotton jassids, and moth caterpillars. Neem is also very effective against beetle larvae, butterfly, aphids and white flies, mealy bug, scale insects, adult bugs, diamond back moth. fruit maggots, spider mites, moth and caterpillars such as Mexican bean beetle and Colorado potato beetle. Neem oil @ 2.0% with 1% detergent found most effective against pod borers complex in chickpea, moong, cowpea and okra, shoot and fruit borer of brinjal. Neem seed kernel extract (NSKE) @ 5% with 1% detergent found most effective against stem borer in rice and management of diamond back moth.

Preparation of Neemastra and Agniastra along with other extracts is described here. These are highly effective for pest management.

**Neemastra:** 200 litre water + 10 litre cow urine (Desi) + 2 kg cow dung + 10 kg neem twigs with leaves + 500 g turmeric powder + 500 g ginger paste + 10 g asafoetida (hing) powder mix it thoroughly and stir with wooden stick clockwise. Keep solution 48 hours in shade then filter the solution. This solution should be sprayed directly on the crop without dilution it controls sucking insects.

**Agniastra:** 20 litre cow urine (Desi) + 2 kg neem leaves (chatani) + 500 g tobacco powder + 500 g hot chilli (chatani) + 250 g desi garlic (chatani) mix this thoroughly and in a low temperature boil it, after boiling keep the solution for 48 hours under shade stir it morning and evening, filter the solution with a cloth and store it. Three litre of extract should be dissolved in 100 litre water and it can be sprayed in general against all sorts of insects.

**Dashparni extract:** Crush neem leaves 5.0 kg, *Vitex negundo* leaves 2.0 kg, *Aristolochia* leaves 2.0 kg, Papaya (*Carica papaya*) 2.0 kg, *Tinospora cordifolia* leaves 2.0 kg, *Annona squamosa* (Custard apple) leaves 2.0 kg, *Pongamia pinnata* (Karanj) leaves 2.0 kg, *Ricinus* *communis* (Castor) leaves 2.0 kg, *Nerium indicum* 2.0 kg, *Calotropis procera* leaves 2.0 kg, Green chilli paste 2.0 kg, Garlic paste 250 g, Cow dung 3.0 kg and Cow Urine 5.0 lit in 200 litre water ferment for one month. Shake regularly three times a day clockwise. Extract after crushing and filtering. The extract can be stored up to 6 months and is sufficient for one acre. Karanj oil @2.0% with 1% detergent is most effective against pod borer complex in chickpea, moong, cowpea and okra shoot and fruit borer.

**Neem-Cow urine extract:** Crush 5.0 kg neem leaves in water, add 5.0 litre cow urine and 2.0 kg cow dung, ferment for 24 hours with intermittent stirring, filter squeeze the extract and dilute to 100 litre, use as foliar spray over one acre. Most effective against sucking pests and mealy bugs.

**Mixed leaves extract:** Crush 3.0 kg neem leaves in 10 litre cow urine. Crush 2.0 kg custard apple leaf, 2.0 kg papaya leaf, 2.0 kg pomegranate leaves, 2.0 kg guava leaves in water. Mix the two and boil 5 times at some interval till it becomes half. Keep for 24 hours, then filter squeeze the extract. This can be stored in bottles for 6 months. Dilute 2-2.5 litre of this extract to 100 litre for 1 acre. Most effective against sucking pests, pod borer and fruit borers.

**Chilli-garlic extract:** Crush 1.0 kg Ipomea leaves, 500 g hot chilli, 500 g garlic and 5.0 kg neem leaves in 10 litre cow urine. Boil the suspension 5 times till it becomes half. Filter squeeze the extract and store in glass or plastic bottles. Dilution of 2-3 litre extract in 100 litre. water is used for one acre. Chilli garlic extract @ 9 kg/ha (8:1) most effective against gall midge, green leaf hopper (GLH), thrips, white fly, semilooper, shoot and fruit borer of brinjal/tomato and tobacco caterpillar of soybean.

**Broad spectrum formulation:** In a copper container mix 3.0 kg fresh crushed neem leaves and 1.0 kg neem seed kernel powder with 10 litre of cow urine. Seal the container and allow the suspension to ferment for 10 days. After 10 days boil the suspension, till the volume is reduced to half. Grind 500 g green chillies in 1 litre of water and keep overnight. In another container crush 250 g of garlic in water and keep overnight. Mix thoroughly and filter the boiled Chilli-garlic extract. This is a broad spectrum pesticide and can be used on all crops against wide variety of insects. Dilution of 250 ml in 15 litre of water for spray.

**Cow urine:** Cow urine diluted with water in ratio of 1: 20 and used as foliar spray is not only effective in the management of pathogens and insects, but also acts as effective growth promoter for the crop.

**Fermented curd water:** In some parts of central India fermented curd water (butter milk or *Chaach*) is also used for the management of white fly, jassids, qreyaphids etc.

### Certification system

In India, there are two accreditation systems for authorizing Certification and Inspection agencies for organic certification. National Programme on Organic Production (NPOP) promoted by Ministry of Commerce is the core programme which governs and defines the standards and implementing procedures. National Accreditation Body (NAB) is the apex decision making body. Certification and Inspection agencies accredited by NAB are authorized to undertake certification process. The NPOP notified under Foreign Trade Development and Regulation (FTDR) act, 1992 and controlled by Agricultural Processed Foods Export Development Authority (APEDA) looks after the requirement of export while NPOP notified under APGMC act and controlled by Agriculture Marketing Advisor, Directorate of Marketing and Inspection looks after domestic certification. Authorized certification agencies to undertake certification process are available at *www.apeda.com/npop*. In 2006, India's organic certification process under NPOP has been granted equivalence with European Union and Switzerland. It has also been recognized for conformity assessment by USDA's NOP.

## SUMMARY

Organic farming provides quality food products and fibers which are beneficial to human health without adversely affecting soil health and environment. Organic farming is a way to keep the soil alive and in good health through the use of biological wastes and other biological materials along with beneficial microbes to release plant nutrients (macronutrients and micronutrients) to crops for increased sustainable production in an ecofriendly, pollution free environment. There is a need to identify suitable crops/ products on agro climatic zone basis as conventional farming is shifting its way towards organic farming. Some agro climatic zones have great potential for organic farming and many products can be produced organically. Trading is a major constraint in organic farming due to policy issues. Organic farming can provide ample opportunities for employment.

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### Organic farming packages and models

Organic farming packages for 4 cropping systems suitable to Gujarat, Kerala, Rajasthan, Sikkim and Uttarakhand were developed as per National Programme for Organic Production (NPOP) standards. Groundnut-wheat-green gram system registered 6.1 t/ha of groundnut equivalent yield with ₹ 1.43 lakh/ha as net returns while cassava-groundnut system in Kerala resulted in cassava tuber equivalent yield of 32 t/ha under organic production system. Fennel-cluster bean system recorded fennel equivalent yield 2.2 t/ha with net income and B:C ratio of ₹ 75,808/ha and 2.21 respectively. Under Sikkim conditions, maize + ginger – French bean resulted in 15 t/ha of maize equivalent yield with net return of ₹ 2.99 lakh/ha.

*Source:* ICAR Annual Report (2020)

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# Use of neem and neem based products

## in organic farming

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*Neem (*Azadirachta indica*) is considered as the most useful traditional plant in India. It is also called "the wonder tree" that has multiple pesticidal, medicinal and anti-feedant properties, making it ecofriendly. Since time immemorial, it has been extensively used in Ayurveda, Unani and Homeopathic medicines. Neem has great potential as an organic amendment for sustainability of environment, health and nutrition. Neem cakes and neem leaves can be used as organic manure, biopesticide, fertilizer coating agent, soil conditioner in organic farming. The natural pesticides obtained from neem are biodegradable, less harmful, least persistent, less toxic to non-target organisms and economical. Fruitful results of applying formulated neem based products in agriculture can provide a cost effective technology to the farming community.*

**Keywords:** Azadirachtin, Biopesticides, Neem cake, Neem coating

IN ancient India, about 60% income was based on agriculture. Land was fertile and it was cultivated using all natural methods and components. At that time, there was no use of pesticides, only natural products like animal waste were used as pesticides. Instead of inorganic chemical fertilizers, only organic manures made with harmless natural ingredients were used. But nowadays, agriculture is mainly dependent on inorganic fertilizers and pesticides. Though these chemicals give more profit but are harmful for human health as well as soil fertility.

Organic farming is a technique which uses natural and biological methods to enhance soil fertility and maintain ecological balance in farming systems. Organic farming makes use of biopesticides, organic manure and bio-fertilizers for nutritional supply to the crop plants. From an environmental standpoint, organic farming is the preferred method for pest and disease control in agriculture. It is considered to be non-toxic, has less input requirements, and greatly enhances the ecological balance while promoting biological diversity and saving the environment.

Sustainable agriculture encourages practices that present low risks to the environment and human health. Neem oil extracted from the *Azadirachta indica* tree contains azadirachtin which is the active ingredient in multiple commercially available biopesticides. Neem based products like neem cake are used for coating inorganic fertilizers to prevent the loss of nutrients. Products derived from neem can contribute to sustainable development and resolve pest control

Neem tree (*Azadirachta indica*)

problems in agriculture.

Scientists world over are now focusing on the importance of neem in the agricultural industry. All the parts of neem tree, viz. leaves, bark, twigs, kernel etc. contain hundreds of active compounds which are antibacterial, antifungal as well as antiviral. Natural properties of neem do not have any toxic effect on plants, soil as well as human beings. Neem products are powerful insect growth regulators (IGR) that regulate several harmful bacteria, fungi and nematode. It reduces insect growth and development in different crops which affects their life cycle and leads to decline in insect population.

Neem tree products are used as organic fertilizer, biopesticides, neem manure, nitrification inhibitor, coating agent in different fertilizers and neem soil conditioners. In recent decades, Neem has attracted worldwide attention mainly due to its bioactive ingredients that find increasing use in organic farming storage grain protection. The terpenoids are the unique chemical compounds found in neem plant. Neem leaves might be used in green leaf manuring, litter compost, mulching and also in storage of grains. Neem leaf extracts have great antibacterial and antifungal properties. The extract is beneficial against leaf eating caterpillars, grubs, locusts and grasshoppers. Neem bark and roots also have medicinal properties.

## NEEM PRODUCTS AND THEIR USES IN ORGANIC FARMING

### Neem as fertilizer

Neem has shown great potential as an organic fertilizer. Neem cakes and neem leaves can be used for this purpose. When it is ploughed into the soil it protects plant roots from nematodes and white ants. It should be applied 30-35 days before sowing of seeds in the field. Neem cake can also be used as a fertilizer, providing the macronutrients essential for plant growth. Among primary nutrients, Nitrogen (N) is one of the major nutrients required by plants for their growth and development, and urea is the main source of nitrogenous fertilizer used worldwide to meet the nitrogen demand of crops. Neem acts as a nitrification inhibitor, which inhibits the activity of *Nitrosomonas* bacteria, so that conversion of $NH_4$-N into $NO_3$-N occurs very slowly. When neem cake is thoroughly mixed with urea, it forms a fine coating on it and protects from the Nitrogen losses by denitrification and ensures continuous availability of nitrogen for a longer period, as per the requirement of different crops. It also stimulates the phosphorus uptake slightly but has no effect on potassium uptake. It is widely used to ensure a high yield of crops. Neem is used as a fertilizer both for food crops and cash crops, particularly rice, cotton and sugarcane. It is harmless to earthworms in fact earthworm populations are known to proliferate in plots treated with neem cake.

### Neem cake

Neem cake acts as a natural manure that does not have any negative impact on soil, plant as well as living organisms. It can be used directly by mixing with the soil or it can be blended with urea and other organic manures like FYM for best results. Neem cake also enrich nutrients in other organic manures like FYM, compost, and vermicompost etc.

Neem cake is completely organic, botanical product containing 100% natural NPK and other micro nutrients in organic form, essential for plant growth. Macronutrients such as Nitrogen (2.0–5.0%), Phosphorus (0.5–1.0%), Potassium (1.0–2.0%), Calcium (0.5–3.0%), Magnesium (0.3–1.0%), and Sulphur (0.2–3.0%) while micronutrients such as Zinc (15–60 ppm), Copper (4–20 ppm), Iron (500–1200 ppm) and Manganese (20–60 ppm) are found in it. The cake is also rich in both sulphur compounds and liminoids. Neem cake improves the soil reaction by reducing its alkalinity and producing organic acids on decomposition. Being completely natural and organic, neem is compatible with soil microorganisms, improves rhizosphere microflora and ensures stable soil structure, high water holding capacity and aeration in the soil for better root development.

Neem cake

### Neem as urea coating agent

Neem and its parts are being used to manufacture urea coating agent to improve and maintain the nitrogenous fertilizer efficiency in soil. Urea is highly water soluble, nitrification and denitrification reduce its efficiency. If urea is coated with neem, the loss can be minimized by slow release of fertilizer, making it available to plants for a longer time. Neem coated urea is ecofriendly which reduces solubility of urea and controls groundwater contamination. The coating reduces ammonia losses through volatilization and controls atmospheric pollution. This environment friendly endeavor can be converted into economic boon for farmers also. It can also be used to control a large number of pests such as caterpillars, beetles, leafhoppers, borer, mites etc. Urea coating with neem is generally done either in liquid form or powdered form. Properties of neem urea coating include anti feedant, and pest growth regulator.

### Neem as manure

Manure is used as organic fertilizer in agriculture. Most of the manure consists of animal excreta and plant materials that improve soil fertility and promote plant growth. Neem manure is gaining popularity because it is environmental friendly and also helps increase the nitrogen and phosphorous content in the soil.

### Neem as soil conditioner

Soil conditioner is a product which is added to the soil to improve soil's physical condition, usually its fertility. It can also enhance soil quality parameters that stimulate the growth and yield of different crops. Neem seeds, usually powdered seeds are used to manufacture the soil conditioner. It can be applied during sowing of seeds or can be spread and raked over the field. The process of raking into the soil should be followed by proper irrigation so that the product reaches the root zone. Organic soil conditioner is gaining popularity in agricultural industry, not only in India but also in other countries. It can also be used in preparation of different inorganic fertilizer as a soil conditioner.

### Neem for storage grain pests

The practice of storing foodgrains is a post harvest technique against adverse weather conditions and insect pest attacks. There are number of species of insect pest that attack granaries and other food structures since ancient times. In India, about 10% foodgrain losses take place during storage at the farm level. It is an old practice in India to mix dried neem leaves with grains meant for storage. Gunny bag should be dipped in 10% neem kernel solution for 15 min. Dry it in shade and use for storing grains. If the gunny bags are new then it should be soaked for half an hour. Stored grains are also fumigated with the smoke of neem leaves in many parts of India. Neem leaves are a good fumigant against storage pests, household and crop pests. Grains and pulses can be stored by mixing them with neem products like dried leaf powder, kernel powder or neem oil. The neem oil used against stored grain pests should be 1% by weight of the grains. If the grain is used for the purpose, 2% can be used. Using oil is easier than leaves. The active ingredient of neem plant is more in seed and kernel. Neem fumigation is non-toxic, eco friendly and does not contaminate the terrestrial and aquatic environment. This fumigant not only kills insect pests but also affects life cycle, growth and development. The main advantage of this fumigant is that pests do not develop resistance to it.

### Neem: a potential biopesticide

Neem is a potential biopesticide for organic agriculture and it is widely used either in Integrated Pest Management (IPM) singly or in conjunction with chemical pesticides. Neem based pesticide is superior to other botanical pesticides such as Rotenone and Pyrethrins. Azadirachtin is the main ingredient of neem plant which is used to manufacture biopesticides. Neem oil and seed extracts are known to possess germicidal and anti-bacterial properties which are useful to protect the plants from different kinds of insect-pests. One of the most important advantages of neem-based pesticides and neem insecticides is that they do not leave any toxic residue on the plants.

Neem based products do not destroy the natural predators and parasites of pests like pollinators, honeybees, mammal etc., thereby, allowing these natural enemies to keep a check on the pest population. Neem also is a systemic biopesticide, therefore, seedlings can absorb and accumulate the neem compounds to make the whole plant pest resistant. Neem oil reduces pest population by not allowing the female to deposit eggs on stored grains or feed on them. It is an Oviposition deterrent. Positive and significant effect of neem products on mortality, growth and reproduction of earthworms has been observed. Neem oil, oilseed cake extracts, commercial neem based products such as Suneem, Suneem G, Nimin, Achook, and Jawan when used as seed-coating were found to be highly effective against nematodes.

## SUMMARY

Neem products are eco-friendly and superior in quality compared to chemical pesticides. By using these products, we can overcome the ecological and health threats imposed by chemical pesticides. Neem based products like neem cakes are a boon for organic agriculture in order to maintain sustainability of environment.

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