INTENSIVE AGRICULTURE

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Address for correspondence

Intensive Agriculture

Joint Director (Farm Information)
Directorate of Extension
Department of Agriculture & Farmers Welfare
Ministry of Agriculture & Farmers Welfare
Government of India
Krishi Vistar Sadan, Pusa, New Delhi-110012
E mail: editor.intensive@gmail.com

EDITORIAL

Farm mechanization in Indian agriculture has witnessed significant strides in recent years, transforming traditional farming practices and offering a promising pathway towards increased efficiency and productivity. Adoption of modern machinery has not only eased the burden on farmers but has also played a crucial role in addressing challenges such as labor shortages and the need for sustainable agricultural practices. Agricultural Mechanization is one of the crucial driver for sustainable development of agriculture sector which helps in increasing production, productivity and household income by better and efficient management of inputs like seeds, fertilizers, water, labour etc to reduce the losses, operational time as well as drudgery associated with various farm operations.

Ministry of Agriculture & Farmers Welfare is promoting Agricultural Mechanization through various schemes and programmes and in order to lay a special emphasis on farm mechanization and to bring more inclusiveness, a dedicated scheme, Sub-Mission on Agricultural Mechanization (SMAM) was implemented from 2014-15. The scheme is being implemented with objectives of increasing the reach of farm mechanization to small and marginal farmers and to the regions where availability of farm power is low; promoting Custom Hiring Centers; creating hubs for hi-tech & high value farm equipments; creating awareness among stakeholders through demonstration and capacity building activities; ensuring performance testing and certification at designated testing centers located all over the country. This scheme also provides subsidy for establishment of Custom Hiring Centers, Farm Machinery Banks & Hiring, Hi-Tech Hubs through which the small & marginal farmers can access to the high cost & appropriate machinery as per their requirements on affordable rental charges/rates. Another component includes farm mechanization in selected villages from the areas with low level of mechanization, with a view to increase productivity and creating ownership of appropriate farm equipments among small & marginal farmers.

The Government has given emphasis to provide financial assistance to the farmers and other target groups for purchasing different kinds of farm equipment and demonstration of new equipments among farmers for widespread adoption of new technology. Emphasis has also been given for development of human resource in operation, maintenance/ repairs and management of agricultural machinery and quality improvement through testing and evaluation besides institutional credit & fiscal measures. The quality and performance testing of Farms Machinery and Implements is being done at four Farm Machinery Training and Testing Institutes and 38 designated Testing Centers at State Agricultural Universities and ICAR institutions.

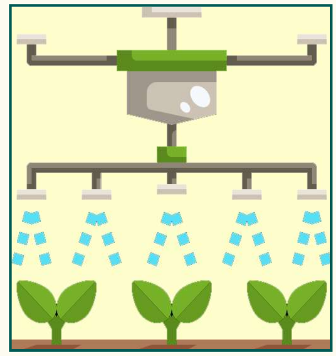
In line with the Budget Announcement for 2022-23, Ministry of Agriculture and Farmers Welfare is promoting the use of Kisan Drones and Kisan Drone technology for modernizing the Agriculture sector. Use of drones in agriculture has distinct advantages like increased efficiency, cost effectiveness due to reduction in cost of spraying, saving of fertilizers and pesticides due to high degree of atomization; saving of water due to ultra-low volume spraying etc besides reduction of human exposure to hazardous chemicals. The use of drones in agriculture also has catalytic effect in creating both direct as well as indirect employment in the agriculture sector. Looking into the unique advantages of Drone technologies in agriculture, a Standard Crop Specific Operating Procedures (SOPs) has been released for use of drones in pesticide and nutrient application. In order to make this technology affordable to the farmers and other stakeholders of this sector, financial assistance for drone together with the contingent expenditure is extended under SMAM.

The Government has recently approved Central Sector Scheme for providing drones to the Women Self Help Groups (SHGs) with an outlay of Rs. 1261 Crores. The scheme aims to provide drones to 15000 selected Women SHGs for providing rental services to farmers for agriculture purpose i.e. application of fertilizers and pesticides. Under this scheme, Central Financial Assistance @ 80% of the cost of drone and accessories/ancillary charges up to a maximum of Rs. 8.0 lakhs will be provided to the women SHGs for purchase of drones. The scheme will help in infusing advance technology in agriculture for improved efficiency, enhanced crop yield and reduced cost of operation for the benefit of farmers. The scheme would also provide sustainable business and livelihood support to SHGs and provide additional income.

Farm mechanization in Indian agriculture signifies a paradigm shift towards efficiency, productivity and sustainability and it has emerged as a key driver of change in Indian agriculture, offering solutions to longstanding challenges. As the country continues to grapple with evolving dynamics of agriculture, a continued collaboration between the government, agricultural communities and technology providers is essential to overcome barriers and ensure that the benefits of mechanization reach to the farmers across diverse landscapes, contributing to a more sustainable, prosperous and resilient agriculture in India.

Dr. Sanjay Kumar Joshi

Machine Learning: Tool of Artificial Intelligence for Empowering Agriculture



Sunil Shirwal, M. Veerangouda, Sushilendra

India holds the record for the second-largest agricultural land in the world, with around 60% rural Indian households making their living from agriculture. The agricultural sector in India employs half of our population and we are greatly dependent on the farmers to provide us with a means of sustenance. In the present scenario, there is a growing need for the transformation of agriculture due to a number of factors including population growth, climate change and increasing demand for food. The agricultural sector is facing significant challenges and without transformation, it may not be able to meet the needs of a growing global population. The transformation of agriculture can be achieved by adopting new technologies, such as precision agriculture, data analytics and machine learning, to optimize production and reduce waste. In agriculture, machine learning has the potential to revolutionize the way farmers manage their crops and livestock, making farming more efficient, sustainable, and profitable.

Agriculture is a crucial sector for human survival, and it has undergone several changes over the years. According to the World Bank, over 80% of the world's poor live in rural areas, and many depend on agriculture for their livelihoods. As per FAO, over 820 million people suffer from chronic undernourishment globally, and the COVID-19 pandemic has further exacerbated the situation. Agriculture is a vital source of income for many people, particularly in developing countries and accounts for around 25% of GDP in low-income countries and around 10% in middle-income countries. Empowering agriculture is crucial for ensuring food security, reducing poverty, and promoting economic growth by increasing their productivity and income. According to the International Fund for Agricultural Development (IFAD), investing in small-scale agriculture can lead to a 4.5% reduction in poverty for every 1% increase in agricultural productivity.

Agriculture is also a significant contributor to environmental degradation, including deforestation, soil erosion and water pollution. Empowering agriculture can help in promoting environmental sustainability by encouraging the adoption of sustainable practices, such as conservation agriculture, agroforestry and organic farming. Sustainable agriculture practices can increase crop yields by up to 79%, while reducing greenhouse gas emissions and improving soil health (FAO). There is a growing need for the transformation of agriculture due to a number of factors including population growth, climate change and increasing demand for food. The agricultural sector is facing significant challenges and without transformation, it may not be able to meet the needs of a growing global population. One key factor driving the need for transformation is population growth. According to the United Nations, global population is expected to reach 9.7 billion by 2050. This will require an increase in food production of up to 70% to meet the demand. However, current agricultural practices are already putting a strain on the environment with soil degradation, water scarcity and deforestation. All these factors are contributing to re-

Department of Farm Machinery and Power Engineering, College of Agricultural Engineering
University of Agricultural Sciences, Raichur, Karnataka, India - 584 104
Corresponding Author e-mail: sunilsshirwal@gmail.com

duced yields and productivity.

Climate change is another factor driving the need for transformation in agriculture. Rising temperatures, changing weather patterns and increased frequency of extreme weather events are all affecting agricultural productivity. According to the World Bank, climate change could reduce crop yields by up to 25% in some regions, leading to food shortages and higher prices. There is also increasing demand for food from a growing global middle class. According to the Organization for Economic Cooperation and Development (OECD), the global middle class is expected to double by 2030, with much of this growth occurring in emerging economies.

To address these challenges, there is a need for transformation in agriculture. This can involve adopting new technologies, such as precision agriculture, data analytics and machine learning to optimize production and reduce waste. It can also involve shifting towards more sustainable agricultural practices such as agroforestry, conservation agriculture and organic farming, to protect the environment and increase resilience to climate change. Technology has transformed the way farmers produce and manage their crops, making farming more efficient and productive. One of the most significant technological advances in agriculture is machine learning.

Machine learning (ML) is an area of artificial intelligence (AI) that focuses on creating computer programs that can learn from data, identify patterns and make decisions without being explicitly programmed. Machine learning has become increasingly popular in recent years with applications in a wide range of fields, including healthcare, finance, marketing and transportation. In agriculture, machine learning has the potential to revolutionize the way farmers manage their crops and livestock, making farming more efficient, sustainable and profitable. One of the main benefits of machine learning in agriculture is its ability to improve crop yields and reduce waste. By analysing data on soil moisture, temperature, weather patterns, and other variables, machine learning algorithms can help farmers optimize irrigation, fertilization and pest management. The use of machine learning in agriculture can increase crop yields by up to 70% and reduce fertilizer usage by up to 50%.

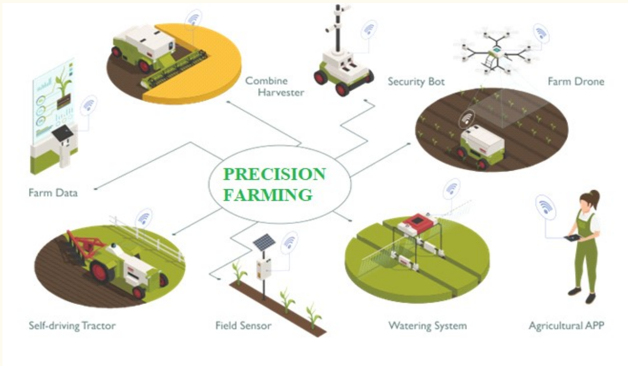
Machine learning can also help address labour shortages in agriculture by automating tasks such as planting, harvesting and sorting of crops produce. According to a report by the USDA, labour shortages are a major concern for the agriculture industry with many farmers struggling to find enough workers to meet their needs. By using machine learning and robotics, farmers can reduce their reliance on manual labour and increase their efficiency and productivity.

Applications of Machine Learning in Agriculture

Machine learning has the potential to change farming practices and can introduce a new agricultural revolution. It has become increasingly important in the farming industry as it can help farmers quickly analyse large amounts of data to make informed decisions and optimize their operations. With machine learning, farmers can gain insights into soil conditions, crop yields and other factors that affect their crops. This information can then be used to create more efficient farming practices and increase yields. Additionally, machine learning algorithms can be used to automate certain tasks such as irrigation or pest control. By leveraging the power of machine learning, farmers are able to maximize their profits while minimizing their environmental impact. The following are the broad areas of agriculture where ML plays a vital role.

a) Precision farming:

Precision farming involves technologies for optimizing use of resources, such as water, fertilizer and pesticides. Machine learning is a valuable tool for precision agriculture, allowing farmers to make more informed decisions about planting, fertilization, watering and harvesting of crops. Machine learning algorithms can help farmers in optimizing their practices to achieve higher yields and reduce waste by analysing data from a variety of sources, including weather patterns, soil moisture levels and crop health. A study conducted in the United States found that using machine learning algorithms to optimize irrigation schedules increases crop yields by up to 30%, while reducing water usage by up to 50%. Another study conducted in China found that



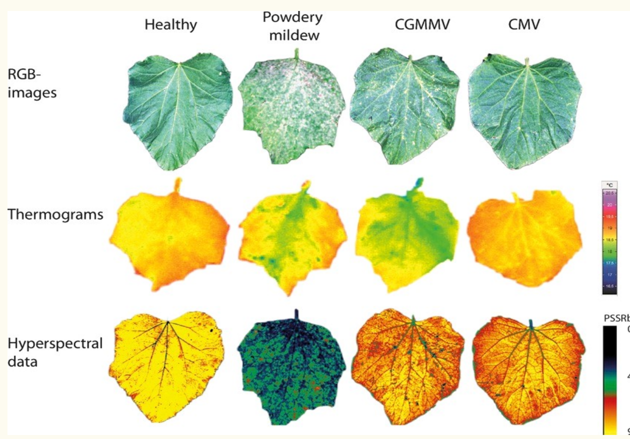
using machine learning to predict crop yields can improve accuracy by up to 80% compared to traditional methods. ML and AI can analyze data from sensors and other sources to determine the precise amount of resources needed for each crop. This can result in significant cost savings for farmers and more sustainable farming practices.

b) Crop monitoring and yield predictions:

Machine learning and artificial intelligence are increasingly being used for crop monitoring and yield predictions in precision agriculture. ML and AI algorithms can analyse images of crops taken from drones or satellites to detect abnormalities or changes in the crops. These technologies can provide farmers with real-time insights on crop health and growth. Algorithms can also predict crop yields based on historical data and current conditions, helping farmers make more informed decisions about when to plant, irrigate and harvest their crops. In addition to improving crop monitoring and yield prediction, machine learning and AI can also be useful for optimizing fertilizer and irrigation use. By analyzing data on soil moisture levels, weather patterns and crop growth, these technologies can help farmers in determining the optimal amount and timing of fertilizer and water application. This can lead to significant savings in input costs while maximizing crop yields. It was found that use of machine learning led to 29% reduction in fertilizer use while increasing tomato yield by 4.3%. Similarly, using AI-based irrigation systems led to 30% reduction in water use while maintaining or increasing crop yields. Machine learning has also been used by scientists to predict crop yields based on weather data and soil conditions, with an accuracy rate of up to 90%.

c) Disease and pest detection:

Machine learning and artificial intelligence have shown great promise in the detection and management of pests and diseases in crops. By analysing large amounts of data, these technologies can accurately identify and diagnose the presence of pests and diseases, allowing for more targeted and effective management practices. A study in Brazil found that using machine learning algorithms to analyse hyperspectral imaging data of citrus trees was able to detect citrus greening disease with an accuracy of over 90%. Scientists have also demonstrated the effectiveness of using machine learning for identify-

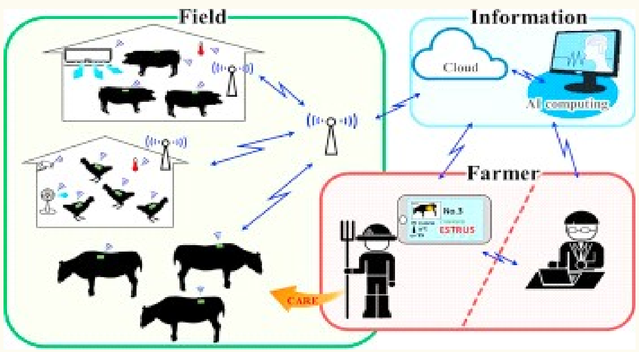


ing and predicting the severity of rice sheath blight disease, with an accuracy rate of over 85%. Machine learning and AI can also be used for pest detection and management. Machine learning algorithms have been used to predict the presence and

distribution of an invasive insect pest, the brown marmorated stink bug in apple orchards.

d) Livestock monitoring and management:

Machine learning and artificial intelligence are also showing great promise in the field of livestock monitoring and management. By analyzing data from sensors and devices, these technologies can provide real-time information on the health and behaviour of individual animals, allowing for more targeted and effective management practices. ML and Swarm Intelligence (SI) algorithms were used to analyse accelerometer data from leg-mounted sensors and was able to detect lameness in cows with an accuracy rate of 90%. The effectiveness of using machine learning has also been demonstrated to predict the onset of illness in pigs based on



changes in their behaviour, with an accuracy rate of up to 93%. A study in Denmark used machine learning to analyse data on the growth and development of pigs, and was able to identify specific factors that influence growth and predict the final weight of pigs with an accuracy rate of up to 93%.

e) Climate risk management and weather forecasting:

To improve climate risk management and weather forecasting in agriculture, ML plays an important role by analysing data obtained from satellite imagery, weather patterns and historical weather data. These technologies can provide more accurate and timely weather forecasts, as well as help farmers manage the risks associated with climate

change viz. drought, floods, unexpected rainfalls etc. A study in Australia used machine learning algorithms to analyze satellite data and other environmental variables to predict droughts up to four months in advance, with an accuracy rate of 82%. Researchers found that the machine learning model outperformed traditional statistical models, a new weather forecasting model that was able to predict rainfall with an accuracy rate of up to 80%, compared to traditional models that had an accuracy rate of around 60%.

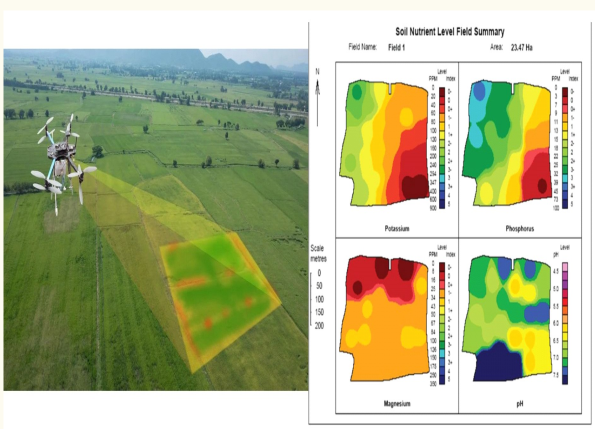
f) Robotic farming:

Automation of several processes such as planting, monitoring, irrigating and harvesting can be achieved by ML, which can increase efficiency and reduce costs. Machine learning algorithms have been used to analyse data from sensors mounted on planting machines and to adjust the seed placement to optimize crop yield. This approach led to a 10% reduction in seed usage, with an increase in yield of up to 8%. Another example is the use of autonomous tractors that can plant, spray and harvest

crops. It was found that autonomous tractors could reduce labour costs by up to 20%, increase crop yields by up to 5% and reduce fuel usage by up to 20%.

g) Soil analysis:

This technology is very useful in soil analysis by providing accurate and real-time insights on soil quality, fertility and nutrient levels. This information can help farmers to make better decisions about their farming practices, such as selecting the right crops to grow, applying the right amount of fertilizer and implementing sustainable soil management practices. Machine learning models are able to analyse soil data and predict nutrient levels and these models have been found to be accurate in predicting nitrogen and phosphorus levels with a correlation coefficient of 0.75 and 0.65, respectively. Apart from these, it can identify areas of soil degradation by analysing satellite images. A model which was able to accurately predict degraded areas was also developed with an overall accuracy of 85.6%.



Challenges of Implementing ML & AI on Farms

Although machine learning (ML) and artificial intelligence (AI) have shown great potential for transforming agriculture, there are several challenges that must be addressed to fully realize their benefits.

a) Data collection and management: ML and AI algorithms rely on large amounts of data to make accurate predictions and decisions. However, collecting and managing data in agriculture can be difficult due to the variability of crop growth, weather patterns and other factors. There is also a lack of standardization in data collection methods, making it challenging to compare data across different farms and regions.

b) Infrastructure and technology adoption: Implementing ML and AI on farms requires significant investment in technology and infrastructure, such as sensors, drones, and computing resources. This can be a barrier for small and medium-sized farms that may not have the resources or technical expertise to adopt these technologies.

c) Technical Expertise: ML and AI require specialized technical expertise to implement and operate. Farmers may lack the necessary skills to develop and implement ML and AI algorithms. They may need to hire data scientists or work with technology partners to implement these technologies.

d) Data privacy and security: As more data is collected and shared between farmers, service providers and other stakeholders, there is an increased risk of data breaches and privacy violations. Farmers must ensure that their data is secure and that they retain ownership of their data.

e) Lack of trust and knowledge: Some farmers may be hesitant to adopt ML and AI technologies due to a lack of trust or understanding of how these technologies work. This can be addressed through education and training programs that help farmers understand the benefits and limitations of these technologies.

f) Integration with existing systems: ML and AI must be integrated with existing farm management systems and practices in order to be effective. This can be challenging due to the complexity of agricultural systems and need to customize algorithms to specific crops and regions.

Addressing these challenges will require collaboration between farmers, technology providers and policymakers to create a supportive ecosystem for ML and AI adoption in agriculture.

Conclusion

Use of ML and AI in agriculture can bring numerous benefits to farmers, including increased effi-

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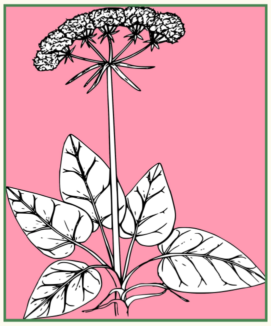
Buckwheat : Important Millet for Human Health



Archana U Singh and Gaurav Thakran

Buckwheat is a pseudo-cereal, not a true grain, and is known for its triangular seeds. It's commonly cultivated for its grain-like seeds, which are gluten-free and rich in nutrients like proteins, fiber and essential minerals. Buckwheat is versatile and used in various cuisines, often ground into flour for pancakes, noodles and other dishes. It's well-suited to cooler climates and has a relatively short growing season. Buckwheat cultivation in India is primarily in the northern states like Himachal Pradesh, Jammu and Kashmir and Uttarakhand. Buckwheat is valued for its short growing season and ability to thrive in poor soil conditions. Farmers often grow it as a secondary crop during the winter season and its cultivation contributes to local economies in these regions.

Buckwheat (*Fagopyrum esculentum*) belongs to the Family Polygonaceae which is distinct from the monocot cereals (Family-Poaceae) and belongs to the category of dicot pseudo-cereals. It is an important crop of temperate region and grown for grains and green leaves. In the higher Himalayas upto 4500 m this is the only crop which can be grown successfully. There are two species of buckwheat cultivated in the India (*F. esculentum* and *F. tataricum*). It is also grown as cover crop to smother weeds and improve soil fertility. The crop seems to improve soil structure and is reported to make more available phosphorus possibly through root-associated mycorrhiza. The flowers are profusely popular with bee keepers and an attractive crop in the landscape. It is cultivated primarily to obtain grains for human consumption. It is also grown for livestock and poultry feeds. The hulls are often used for stuffing pillows. The protein is of high quality due to its high lysine content which is normally deficient in cereal products. It is a healthy food option because of rich essential nutrients including protein and minerals. It is known to contain various anti-oxidative compounds such as vitamins B1, B2, and E and phe-

Buckwheat field

Buckwheat flowers

Division of Nematology, ICAR-IARI, New Delhi-12
corresponding author email: arch_212@yahoo.com

nolic compounds such as Rutin, Quercetin and Proanthocyanidines (condensed tannins).

Distribution in India

The important areas of buckwheat cultivation are Udhampur, Ladakh, Kargil and Drass sectors, Gurez valley of Jammu and Kashmir; Kullu, Kinnaur, Bharmaur, Pangi, outer Saraj, Chopal, Dodrakuar, Neshang, Pooh division, Lahaul valley, Pin valley, Shimla in Himachal Pradesh; Pindari valley, Darma valley, Jolwan, Jaunpur, Kapkot in Uttarakhand; Cooch Behar, Darjeeling in West Bengal; Lachan, Lachoong in Sikkim; Tawang, Bomdilla and Dirang in Arunachal Pradesh other higher elevations of Meghalaya and Manipur and also sporadically in the Nilgiris and Palani hills in the southern part of India.

Importance of buckwheat for human health

Buckwheat is highly nutritious whole grain and considered to be a super food. It may improve heart

Buckwheat Bread

Buckwheat Noodles

function, promote weight loss & help in diabetes control. It is a gluten free food and important dietary alternative for celiac disease. It is an ingredient of every day food such as breakfast, flour and noodles for many people. Farmers also use it as livestock feed. The following are possible health benefits of adding buckwheat to the diet:

1. Boosting heart health- It is a good source of fibre and niacin which improves blood cholesterol level and reduce the risk of heart disease and stroke.

2. Improvement in condition of digestion system.

3. Weight management- Preventing weight gain and promoting weight loss.

4. Managing diabetes- It is source of complex carbohydrate so can help in managing blood glucose level.

Nutrition value

Buckwheat is a good source of protein, fiber and carbohydrate. One cup or 168gm of roasted cooked buckwheat hulled seeds contain the following nutri-

Comparison of nutritive value (%) of Buckwheat with other Cereals and Millets in India

Nutrients	Common Buckwheat	Tartary Buckwheat	Wheat	Whole Rice	Milled Barley	Maize	Dry Jowar(a)	Ragi (b)	Varagu (c)	Bajra (d)
Energy	343	328	322	356	316	334	334	321	332	348
Carbohydrates	71.5	74.3	64.7	78.2	61	65	67.7	66.8	66.2	61.8
Protein	13.3	10.3	10.6	7.9	10.9	8.8	10	7.2	8.9	11
Lipids	3.4	2.5	1.5	0.5	1.3	3.8	1.7	1.9	2.5	5.4
Dietary Fibre	10	6.3	11.2	2.8	15.6	12.2	10.2	11.2	6.4	11.5
Ash	2.1	1.8	1.4	0.6	1	1.2	1.4	2	1.7	1.4
Moisture	9.8	10.2	10.6	9.9	9.7	9.3	9	10.9	14.2	9

Source: Adapted from *Przybylski and Gruczynska* [11] and Indian Food Composition; in Table : (a) Jowar (*Sorghum vulgare*); (b) Ragi (*Eleusine coracana*); (c) Varagu (*Setaria italica*); (d) Bajra (*Pennisetum typhoideum*)

Buckwheat Grains

Buckwheat Flour

ents:

1. Protein –5.68g
2. Phosphorus-118mg
3. Magnesium-86mg
4. Calcium-12mg
5. Iron-1.34mg
6. Fat-1.04g
7. Carbohydrate-33.5g
8. Fiber-4.5g
9. Potassium-148mg

Crop description

Origin- Buckwheat originated in the Tibetian Plateau or nearby mountain of Yunnan, SW China.

Chromosomal No. – 2n=16

Species- *Fagopyrum cymosum* is considered as wild species of cultivated buckwheat. There are two species of buckwheat cultivated in the Himalayan hills (*F. esculentum* and *F. tataricum*).

Inforescence- The inflorescence is compound raceme that produces flowers in cymose cluster laterally.

Fruit- Fruit is an achene with single seed similar to sunflower seed.

Varieties-

1.Common Buckwheat - *F. esculentum*

2.Tartary Buckwheat - *F. tataricum*

Local cultivars are Mithey, Tithey, PRB-1, VL-Ugal and Sangla B-1

Sowing Time- It is a short duration crop and sown in Summer from April to mid-July. As a Cover crop it can be planted in early summer or late spring.

Seed Rate- 18-25 Kg/acre.

Field preparation- The field which has recently been cleared for cultivation is prepared after one deep ploughing followed by two harrowing/tilling and planking. This results in good germination and uniform stand of the crop. It may also help the crop to achieve higher rate of establishment and early growth. As a cover crop it does not require extensive land preparation and can grow well on poorly tilled soil.

Soil- Buckwheat grows well in properly managed soil with moderate fertility. It tolerates soil pH level as low as 4.8. It does not tolerate flooding or drought condition. It is an efficient crop in extracting phosphorus having low availability in soil. It has higher tolerance to soil acidity than any other grain crop. It is sown in well drained, sandy loam to silt loam soil.

Climate requirement- This crop is cultivated in cool and moist climate. It can be grown at high altitudes because its growing period is short and heat requirement for development is also lower. The crop is extremely sensitive to unfavorable weather conditions and is killed quickly by freezing temperature or high temperature and dry weather. At blooming time unfavorable temperature can cause blasting of flowers and prevent seed production. The ideal temperature for crop is 21°C. It doesn't tolerate frost. The coldest temperature it can tolerate is about 10°C. Germination of Buckwheat seeds takes place at temperature range of 7-40°C. Plant will emerge from soil in 3-5 days after sowing.

Nutrient management - It absorbs 47 kg Nitrogen, 22 kg Phosphorus and 40 kg Potassium from the soil for each hectare planted and gives yield of 1600 kg/ha. It does not respond well to the nitrogen fertilization hence, nitrogen should be applied on the basis of soil test value. High application of nitrogen can create weed problem, encourages excessive vegetative growth which causes lodging and decreases grain yield. ICAR-NOFRI (earlier ICAR Sikkim Centre) recom-

mends application of Azophos seed treatment + mixed compost @ 5 t/ha+ neem cake @ 0.5 t/ha for obtaining good crop yield. *Azospirillum* spp. and *Azotobacter* spp. thrives well in acidic soils and their combined application resulted in better crop productivity and positively influenced soil biological properties.

Weed management - Limited options are available for weed control in this crop hence, it may limit to certain cultural and mechanical practices. Although plants are very good competitor for weeds and their fast growing capacity makes them a smother crop. Under such conditions one weeding and hoeing at 20-25 DAS is helpful for raising good crop. Firstly, crop should be seeded into fine, firm and weed-free seed bed. Secondly, seed should be placed into moist soil to ensure quick germination and emergence. These practices help the crop to compete with any emerging weeds. ICAR-NOFRI standardized the use of biomulches in buckwheat crop. Maize Stover + weed biomass mulch not only reduces weed population but also enhances water use efficiency in buckwheat crop.

Hilling - Buckwheat tends heavy branching capacity and weak stems, which makes them susceptible for lodging. The plants lodge easily thus hilling at 30-35 DAS stage is required. Lodging is dependent on the plant population and on gaps between plants. Therefore, it is recommended that plant population should be kept at optimum so that yield should not be reduced due to lodging.

Harvesting- It is harvested when grains are 8-10 week mature and even though plant is still green when seed turn dark brown. Timely harvesting of plants is essential to prevent shattering of grains. Generally late harvesting was observed in high altitudes while early harvesting was done in the mid and low altitude areas.

Yield- Yield of 12-14 q/ha is expected from well managed crop. The plant shows irregular time of maturity because of indeterminate growth habit. If harvesting is delayed, shattering of grains starts which causes huge loss. Careful handling of the crop is important because grain shattering results in losses up to 25 per cent. Due to its gradual formation and maturity, harvesting is done periodically and finally crop is cut and then threshed when rest of the seeds are fully matured. The harvesting period is not limited in Tartary (*Tithey*) buckwheat (*F. tataricum*) as compared to common (*Mithey*) buckwheat (*F. esculentum*). The '*Mithey*' type matures earlier than '*Tithey*' type. After harvesting, seeds must be well-dried and kept at about 14 per cent or less moisture for the safe storage of buckwheat grains. However, over-matured seeds when in contact with high moisture germinate very quickly as seeds have vivipary characteristics.

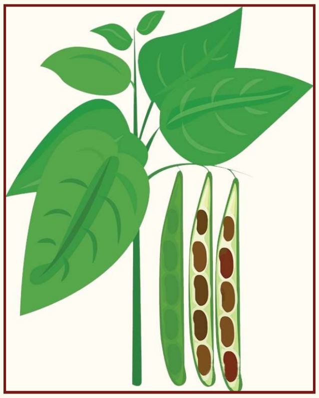
Conclusion

Buckwheat is distinct from monocot cereals and belong to the category of dicot pseudo-cereals. The protein of buckwheat is of high quality due to its high lysine content which is normally deficient in cereal products. It is rich in essential nutrients including protein, minerals, carbohydrates, fiber and known to contain various anti-oxidative compounds which make it a healthy food option. It is also grown for livestock and poultry feeds. It has multiple health benefits and it can improve heart function, promote weight loss & help in diabetes control. It is a highly nutritious whole grain which is considered to be a super food.

Continued from page 8

ciency, improved yields, climate risk management, precision farming, livestock management and decision support. As technology continues to evolve, we can expect to see even more advances in ML and AI that will further improve agricultural practices. It has the potential to revolutionize agriculture by improving crop yields, reducing waste and enabling better decision-making. As the demand for food continues to grow, use of machine learning in agriculture is expected to increase, with significant social, economic and environmental benefits.

Improved Cultivation Practices for Rajmash In India



Basavaraja T[1*], Anupam Tripathi,[1] Manjunatha L[3], Gurumurthy S[2], Aditya Pratap [1,] PK Katiyar[1] and C Mahadevaiah[3]

Rajmash or kidney bean holds a cherished place in Indian cuisine, and its cultivation plays a pivotal role in the agricultural landscape of the country. Rajmash is one of the remunerative grain legume crops of northern plains and north eastern hilly tract of India. The cultivation of rajmash is carried out during both the Kharif and Rabi seasons and the crop typically takes approximately 120 to 130 days to reach maturity. Beyond its agricultural significance, rajmash holds immense cultural and dietary importance in India. It is a staple in numerous households, featuring prominently in a variety of traditional dishes. The cultivation of rajmash not only sustains livelihoods but also contributes to the diversification of crops in the agricultural landscape.

Rajmash (*Phaseolus vulgaris* L., 2n=2x=22) is an important grain legume crop for direct human consumption worldwide. It is popularly known as a common bean, kidney bean, snap bean, runner bean, and string bean in different common bean producing countries. It is a highly nutritious food containing protein, fiber, complex carbohydrates, vitamins and micro-nutrients. The main product of rajmash crop based on usage is dry bean (harvested at complete maturity), shell bean (seeds harvested at physiological maturity), and French bean (fresh tender/green pod with reduced fiber harvested before the seed development phase). In India, the common bean, popularly known as rajma is mainly produced by resource-poor farmers having small and marginal land holding in the traditional production system that includes rotation with vegetables and inter-

Rajmash plant with pods

[1]ICAR-Indian Institute of Pulses Research, Kalyanpur, Kanpur
[2]ICAR-National Institute of Abiotic Stress Management, Baramati
[3]ICAR- Indian Institute of Horticultural Research, Bangalore
*Corresponding author email: basu86.gpb@gmail.com

Seed colour variation in Rajmah

cropping with climbing/ pole type varieties with grain amaranth, potato, and maize during *Kharif* season in the hills.

In contrast, it is grown as the sole crop during *Rabi* season in India's northern and central parts. This is the most common ingredient for preparing delicious and popular north Indian recipes such as rajma chawal, rajma masala and rajma soup. It is mainly grown in hilly areas of Himachal Pradesh, Jammu and Kashmir, Uttrakhand, Sikkim and some plain regions of Uttar Pradesh, Maharashtra and Andhra Pradesh. In hills, it is grown as a *Kharif* crop, whereas in plains grown as a *Rabi* crop. Over time, it is observed that the area and production of the rajmash crop have been increased significantly with the introduction of rajmash varieties in new production niches such as the North-Eastern plains and central India.

Climate requirement

Rajmash grows well in areas where medium rainfall occurs but is not suited to humid conditions. Seed germinates in 12 days at a soil temperature of 15°C-18°C and seven days at 25°C. The optimum mean daily temperature for establishing a good crop is between 15-30°C. The minimum daily temperature for healthy plant growth is 10°C, and the maximum is 27°C. Excessive rain and hot weather cause flower and pod drops and increased incidence of soil-borne and viral diseases.

Soil

Rajmash can be cultivated in various soils, from sandy to heavy clay. However, this crop thrives best in well-drained loamy and light alluvial soils. This crop is very sensitive to salinity and soil pH. Therefore, pH of the soil should be in the range of 5.5 - 6.0 to obtain maximum yield.

Cropping systems

An experiment at IIPR revealed that the rajmash + potato intercropping was profitable and efficient in central Uttar Pradesh irrigated areas. The intercropping of rajmash + potato was more productive and efficient under all planting geometry than sole rajmash. However, the highest productivity (3956 kg/ha) was obtained under the 3:2 row ratio of potato + rajmash intercropping system with a 48 percent increase in land use efficiency. In the hills, it is intercropped with maize and soybean, which is highly recommended for small and marginal farmers to achieve attractive income. It is grown as an intercrop with maize in 1:2 ratios. In-between two rows of maize sown at 90 cm apart, two rows of rajmash are adjusted at 30 cm spacing with the plant population of 120000 rajmash and 40000 maize.

Table 1: Possible new niches for rajmash production

Cropping systems	Possible niches	Expected area (m ha)	Suitable varieties
Maize-rajmash-mungbean	Central and Western UP, North Bihar	0.07	**Mungbean**: Pant Mung 2, PDM 11, HUM 2 **Rajmash:** HUR 137, HUR 15, PDR 14, Amber
Rajmash +potato	Eastern and Central UP.	0.03	PDR 14, Amber

Improved varieties

The choice of variety depends on the overall cropping system, sowing time and source of irrigation in the cultivation area. Choosing an appropriate variety is extremely important for realizing the optimum productivity of the rajmash crop in any production environment. Improper choice of the variety would

Table 2. List of rajmash varieties released in India

Name of variety	Centre responsible for developing	Year of release	Average yield q/ha	Days to maturity	Reaction to major disease	Area of adapta tion
HUR 15	BHU, Varanasi	1989	16-20	120	Mod. Susceptible to	NEPZ
HUR 137	BHU, Varanasi	1991	18-22	112-120	Sus. To BCMV	NEPZ
IPR 96-4 (Amber)	IIPR, Kanpur	2002	15-16	139	Res. To BCMV & leaf crinckle	NEPZ
IPR 98-5	IIPR, Kanpur	2005	17	122	Tol. To BCMV	NEPZ
IPR 98-31(Arun)	IIPR, Kanpur	2007	16	120	Tol. To BCMV	CZ
PDR 14 (Uday)	IIPR, Kanpur	1987	16-20	125	Tol. to BCMV	NEPZ
Gujarat Rajma-1	SDAU, SK Nagar, Gujarat	2004	18	98-100	Moderate resistant to	CZ
VL rajma-63	VPKAS, Alomra	2007	12	110	Resistant to root rot	NHZ
VL Rajma-125	VPKAS, Alomra	2007	12	98-100	Resistant to Bacterial Blight	NHZ
Triloki	CSK, HPKV, HAREC, Dhaulakuan	1998	25-27	98-100	Res. To Bean Anthracnose	NHZ
Kanchan	CSK, HPKV, HAREC, Dhaulakuan	1992	12-15	90-100	---	NHZ
Basapa (KRC 8)	CSK, HPKV, HAREC, Dhaulakuan	1994	18-20	110-120	Res. To Bean Anthracnose	NHZ
Kailash (SRC 74)	CSK, HPKV, HAREC, Dhaulakuan	2003	18-20	120-125	Res. To Bean Anthracnose	NHZ
Jawala (HPR-12)	CSK, HPKV, HAREC, Dhaulakuan		16-20	100-110	Susceptible to Anthracnose	NHZ
Shalimar Rajmash-01	SKUAST-K, Srinagar	2005	12	115-110	Res to root rot and anthracnose	NHZ
Shalimar Rajmash-02 (SKU-AR 132)	SKUAST-K, Srinagar Centre	2018	12-13	100-115	Moderate resistant to BCMV and resistant to	NHZ
Kota Rajmash 1 (RKR1033)	AU, Kota, Rajasthan	2018	15-18	98-104	Resistant to Anthracnose and Angular	CZ

(**Note:** NEPZ: North-eastern Plain Zone, CZ: Central Zone and NHZ: North hill zone)

result in low productivity, even when adequate quantities of inputs are applied. Suitable varieties listed for plains and hills are presented in table 2.

Sowing time

Rajmash is grown in both *Rabi* and *Kharif* seasons in various parts of India, and the sowing season of rajmash varieties varies from state to state. In the Northern plains like Uttar Pradesh and Bihar regions, mid-October is the best time for sowing *rabi* rajmash, and the crop might be harvested during March end or 2nd week of April. Accordingly, it is grown as a spring-summer crop in lower hills like parts of Jammu and

Table 3. Sowing time of rajmash in different states of India

SI. No	States	Season	Time of Sowing
1	Uttar Pradesh	*Rabi*	October (M) to November (B)
2	Bihar	*Rabi*	October (M) to November (M)
3	Andhra Pradesh	*Rabi*	August (E) to September (M)
4	Madhya Pradesh	*Rabi*	October (E) to November (M)
5	Maharashtra	*Rabi*	October (E) to November (M)
6	Jammu and Kashmir	*Spring Summer*	March (M) to April (M)
7	Uttarkhand	*Kharif*	May (M) to June (M)
8	Himachal Pradesh	*Kharif*	May (M) to June (M)

B: Beginning, M: Middle, E: End

Kashmir. Likewise, the upper elevations cultivate as *Kharif* season crops in states like Uttarakhand, Sikkim, and Himachal Pradesh. It is ideally sown from the Middle of May to the Middle of June.

Field preparation

A well-prepared seedbed is required for proper germination and establishment of the crop. A good seed bed has friable but compact soil, adequate moisture and free from weeds and plant debris of earlier crops. Acidic soils of the hills must be treated with lime before sowing. For this 2 to 3 ploughing should be given by tractor or local desi plough in the main field, and the soil must be pulverized with a levelled field which makes the soil to a fine tilth. Apply Farm Yard Manure (FYM) or any organic compost to make the soil rich in fertility. Field must have good internal drainage, so the water stagnation could be avoided. Pre-sowing irrigation before tillage should be ensured for rajmash cultivation after the harvest of preceding crops.

Crop geometry and seed rate

Seed rate varies with seed size. Bold seeded varieties with a test weight of 350-450 g need 120-140 kg seed/ha, while small-seeded varieties vary from 70-100 kg/ha. The seed rate in intercropping may vary with row proportions.

Table 4. Crop geometry for rajmash crop

Location	Varietal type	Row to row spacing	Plant to plant
Plains	Bush	35 cm	8-10cm
	Pole	45 cm	12 cm
Hills	Bush	35 cm	8-10cm
	Pole	45-50 cm	12 cm

Seed inoculation/ dressing

To control soil and seed-borne diseases and better yield, seeds should be treated with antifungal bioagents, root nodulating, and biological N_2 fixing bacteria such as *Rhizobium* and Phosphate Solubilising Bacteria (PSB) such as *Bacillus megatherium and Bacillus polymixa*. The rajmash seeds treated with captaf (or) thiram @ 4 grams/kg seeds (or) carbendazim @ 2 g/kg seeds, protect the crop from soil-borne pathogens.

Fertilizer requirement

Unlike other rabi pulses, rajmash is inefficient in biological nitrogen fixation due to poor nodulation. Hence, it requires relatively higher doses of nitrogenous fertilizers for enhanced productivity, application of 90-120 kg N/ ha has been found optimum. Half of the nitrogen should be applied as a basal dose during sowing and the rest as a top dressing after first irrigation. Its phosphorus requirement is distinctly higher than other pulse crops, a significant response to phosphorus application has been obtained up to a level of 60-80 kg P_2O_5/ha, and potassium hardly affects the yield.

Irrigation

This crop requires pre-sowing irrigation for better germination of the seed and the critical stage for irrigation is about 3 to 4 weeks after sowing. However, it is grown as a rabi crop in northern plains and requires three irrigations, it should be given at different stages of crop growth condition, usually, first irrigation given @ 35 days after sowing, subsequent irrigation given @ 65 and 100 days after seed sowing for optimal yield.

Weed management

One hand weeding/hoeing at 30-35 days after sowing or applying a pre-emergence herbicide like pendimethalin @ 0.75 to 1 kg a.i./ha in 500-600 liters of water (or) 1 kg/ha of fluchloralin should be followed as a part of the pre-plantation process.

Major diseases management

a) Anthracnose**:** Avoid overhead irrigation, seed treatment with carbendazim and thiram @2gm/ seeds kg (1:1), Spray Mancozeb 0.25 % or Carbendazim 0.1 % of 2-3 foliar spray at 45, 60, 75 DAS.

b) Bean common mosaic virus (BCMV): Rouging of infected plants, growing of resistant cultivars such as Amber, Arun, and Utkarsh, foliar spray of metasystox (0.05%) or dimethoate (0.2%) at 45 DAS.

c) Fusarium **root rot:** Use of resistant cultivar VL Bean 2, soil drenching with chemicals like thiram (0.56 kg/ha) and Busan 30A reduces fusarium root-rot severity on hypocotyls and roots of young seedlings

d) Angular Leaf Spot: Crop rotation with non-host seed treatment with fungicides such as mancozeb is more effective.

e) Powdery Mildew: Use of resistant rajmash cultivars such as Amber and Arun, Spray foliar fungicides such as mancozeb 2g/liter and chlorothalonil (kavach) 2ml/liter at 15 days' interval after first appearance of disease.

Major insect management

a) Black Aphids: Spraying of neem or canola oil are the best method of control, setting up of 10-15 yellow/blue/sticky traps/acre at 15 cm above the crop canopy for monitoring and mass trapping of aphids, Biocontrol by releasing of *Coccinella septempunctata* @ 1000 adult/400 m^2

b) Leaf Miner: Roughing of infected leaves, neem water extracts, and neem oil gives good control of leaf miners, spray oxydemeton methyl (metasystox) @1ml/liter of water and if required, repeat at a 15-day interval

Harvesting & threshing

Generally, rajmash matures in 125-130 days. Plants are cut with sickles after attaining full maturity judged by severe leaf fall, changing the color of pods, and hardness of the grains. Harvested materials after 3-4 days' sun drying are collected in bundles to the threshing floors. Threshing is done by beating with sticks or trampling under the feet of bullocks. The clean seed should be sun-dried for 3-4 days to bring its moisture content to 9-10 percent.

Threshing is done by beating with sticks

After threshing

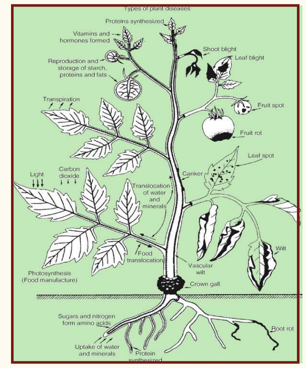
Yield

A well-managed crop can easily give 15-22 q/ha yield under irrigated plain conditions and 5-10 q/ha under rain-fed conditions of hilly regions with 18-25 q/ha of straw as cattle feed.

The following recommendations should be followed to achieve higher production of rajmash:

- Deep summer plowing once in 2-3 years
- Seed treatment should be done before sowing
- Application of fertilizer should be based on soil test value
- Weed control should be done at the right time
- Adopt an integrated approach for plant protection

New-age Technologies in Managing Root and Foliar Diseases of Pulses



Upasna Priya[1], RN Gupta[1], CK Panda[2], JN Srivastava[1] and Abhijeet Ghatak[1*]

Pulse crops are one of the important pillars that sustain food and nutritional security. In our country, biotic causes are one of the major constraints in pulse crop cultivation. Among biotic issues, a few foliar diseases and root-borne diseases play role in drastic reduction of pulses production. There are several practices for management like following crop rotation, using biocontrol agents, using resistance cultivars, and lastly, fungicides are applied to cope-up with such diseases. In view of the existing technologies, new updates should be applied to enrich the management strategies. In addition to the above technologies, application of new-age technologies like next-generation sequencing (NGS), Reinforcement Learning (RL), Machine Learning (ML), Artificial Intelligence (AI) and the Internet of Things (IoT) can play an important role in pulses disease management. These technologies would be helpful for farmers in increasing pulses production, thereby uplifting their social status.

Chickpea (brown and green), pigeon pea, field pea, black gram, green gram, lentil, faba bean, red kidney beans, cowpea and black-eyed beans are the eleven types of pulses recognized by the United Nations Food and Agriculture Organization (FAO). Pulses are essential for people who eat a cereal-based diet to maintain their nutritional requirement. Furthermore, pulses also play a crucial role in thriving intensive agriculture by increasing the biological as well as physicochemical properties of the soil in addition to their nutritional value and ability to fix nitrogen. The pulse crops have been an essential part of agricultural system of cropping over the last three decades. Biotic stress is one of the major constraints that reduces pulse production. Plant diseases involve a large fraction of losses caused due to biotic stress.

Fungi are amongst the most common pathogens that cause pulses diseases, which primarily affect leaves, stems, roots and pods. Fungi such as *Ascochyta*, *Cercospora*, *Erysiphe*, *Fusarium*, *Peronospora*, *Uromyces* and some other fungi cause foliar diseases and root diseases in pulses. Some root diseases of pulses have been listed in table 1.

Leaf spots, blights, rusts and mildews are common symptoms of fungal leaf diseases, while rot and wilt are common symptoms of root diseases. However, premature ripening and increase in severity is observed due to leaf spots, blights, rusts, mildews, root rots, and wilting further results in yield reduction. It is critical to manage fungal diseases to increase the yield potential of pulses. There are several resistant varieties available for different diseases caused due to foliar infection. There are several foliar diseases of pulses caused by different fungal species. Some major foliar diseases of pulses are mentioned in table 2.

The foliar diseases are also managed by using foliar application of synthetic fungicides. In another

[1] Department of Plant Pathology, Bihar Agricultural University, Sabour – 813210
[2] Department of Extension Education, Bihar Agricultural University, Sabour – 813210
* Corresponding author email: ghatak11@gmail.com

Table 1: List of some important root diseases of pulses

S.N.	Crop	Diseases	Causal organism	Control measure/ IPM
1.	Lentil (*Lens culinaris*)	Collar rot or root rot	*Sclerotiun rolfsii*	i) Use of *Trichoderma viride* along with neem cake helps in reducing disease incidence ii) Seed treatment with *T. harzanium* and *Pseudomonas fluorescens* @ 5g/ kg seeds each at time of sowing iii) Crop rotation iv) Deep ploughing
2.	Black gram (*Vigna mungo*)	Dry root rot	*Rhizoctonia bataticola*	i) Avoid poorly drained soils ii) Use of disease free seeds iii) Drenching of soil should be done with pesticide, it helps in reducing damping off in seed beds and greenhouse
3.	Green gram (*Vigna radiata*)	Root rot	*Rhizoctonia bataticola*	i) Avoid poorly drained soils ii) Use of disease free seeds iii) Drenching of soil should be done.
4.	Field pea (*Pisum sativum*)	Rhizoctonia root rot	*Rhizoctonia solani*	i) Rotation with non-host crops for at least 3 years

Table 2: Major foliar diseases of pulses with paramount importance

S.N.	Crop	Diseases	Causal organism	Control measure/ IPM
1.	Chickpea (*Cicer arietinum*)	Ascochyta blight	*Ascochyta rabiei*	i) Crop rotation practices ii) Use of disease-resistant genotypes
2.	Lentil (*Lens culinaris*)	Rust	*Uromyces viciae-fabae*	i) Use of clean seeds ii) Host plant resistance
3.	Cowpea (*Vigna ungiculata*)	Anthracnose	*Colletotrichum lindemuthianum*	i) Use of resistant/ tolerant varieties ii) Use of clean seeds having dressing with isolates of bio-agents such as *Trichoderma viride* or phyto-extracts such as neem extracts iii) Seed treatment iv) Crop rotation with non- host crops such as cereals or cassava
4.	Faba bean (*Viciae faba*)	Chocolate leaf spot	*Botrytis fabae* and *B. cinerea*	i) Usage of the disinfected seed ii) Pursuing crop rotation
5.	Field pea (*Pisum sativum*)	Powdery mildew	*Erysiphe pisi*	i) Use of resistant cultivars ii) Regular application of overhead irrigation
6.	Pigeonpea (*Cajanus cajan*)	Sterility mosaic	Pigeonpea sterility mosaic virus	i) Host plant resistance
7.	Mungbean (*Vigna radiata*) and black gram (*Vigna mungo*)	Yellow vein mosaic	Mungbean yellow mosaic virus	i) Cultivation of resistant varieties ii) Manipulation in sowing dates iii) Inter/ mixed cropping of mungbean and urdbean with non-host crops like sorghum, pearl millet and maize iv) Reducing vector population

case, the best option for root disease management is integrated disease management (IDM) practices. IDM is an effective tool of disease management against diseases. Farmers use disease management components such as agronomic practices including sanitation and other strategies that avoid the critical time for onset of a particular/ targeted disease. Besides this, host plant resistance (HPR), use of biocontrol agents and fungicide application are employed to achieve maximum yield and to promote pulse production. Several fungi like *Fusarium* spp., *Macrophomina phaseolina*, *Rhizoctonia solani* and *Sclerotium rolfsii* are identified as the key players of root rot and wilt disease complex. Apart from the use of resistant varieties, the biopriming using *Trichoderma* has been reducing the extent of root-borne disease in pulses. The areas having high severity incidence of a root disease complex, fungicidal seed treatment is a promising option under the unavailability of resistant genotypes, and thus, less root-borne issues are obtained. On several occasions, biofumigation has been found effective in reducing the occurrence of root-borne issues in pulses. Although, several pathogens in this complex are found to have partial resistance, however, it is not yet found to be available in the commercial cultivars. Root rot management has been shown to be influenced by the cultural practices, particularly crop rotation diversification, as well as early and shallow sowing. The biocontrol agents may also have long-term potential in root rot management. Improved methods for identifying and quantifying pathogen inoculum in individual fields are being developed, which could help farmers to pick IDM packages that can improve yield stability, avoiding high-risk fields.

The occurrence of pulse diseases is immensely affected by weather parameters (viz. temperature, humidity, sunshine hour, rainfall) and new-age technolo-

gies like Artificial Intelligence (AI), Machine Learning (ML), Reinforcement Learning (RL) and Internet of Things (IoT) can assist in managing these diseases of pulses. Application of AI and other important tools like ML etc is very much useful in developing a pulses disease management support system (Figure 1). This can be further used for providing information in the portal so as to get early information for precaution, which can ultimately protect the crop from disease-associated loss. Beyond these, use of drones in monitoring of plant diseases is a vital example of new-age approach being implemented in the management of diseases in pulses.

Management of different root diseases

Weather factors play significant role in disease development at different growth stages of pulse crops. Root rot and wilt complex are serious disease problems particularly where high temperature and high moisture, as well as low soil moisture content, are prevailing during growing season of crop. Weather variables play crucial role in the activation, growth and multiplication of pathogen and subsequently resulting in disease development. Information regarding timing of pathogen infection and progression of disease in relation to weather conditions is necessary for prediction of disease occurrence and their management.

Significant progress has been achieved over the past decade in discovering active component combinations that are effective against *Fusarium* spp., *R. solani* and *Pythium* spp. in pulse crops. Cultivars that are resistant to root rot disease complex on a broad scale would be useful disease management tool of pulse crops and this tool would also be cost-effective. Due to the lack of commercialized cultivars having high resistance values, seed treatments have always been and will remain a vital aspect of managing pulse root rot disease. Seed treatments with the use of biological agents have the potential to be a strong technique for controlling root rot in pulses. At present, there are few commercially available biofungicides consistently effective against seedling blight and root rot of pulses. Next-generation sequencing techniques are being developed to rapidly quantify pathogens that cause root rot in host tissue. This method could be utilised in large-scale population research to better understand the root rot disease complex's host-pathogen and pathogen-pathogen interactions. Majority of root rot management strategies emphasise on minimising inoculum pressure and enhancing crop health and vitality. Two ways to lower inoculum density are maintaining diversified agricultural rotations involving non-hosts (not always feasible, e.g. *F. avenaceum*) and avoid strongly in-

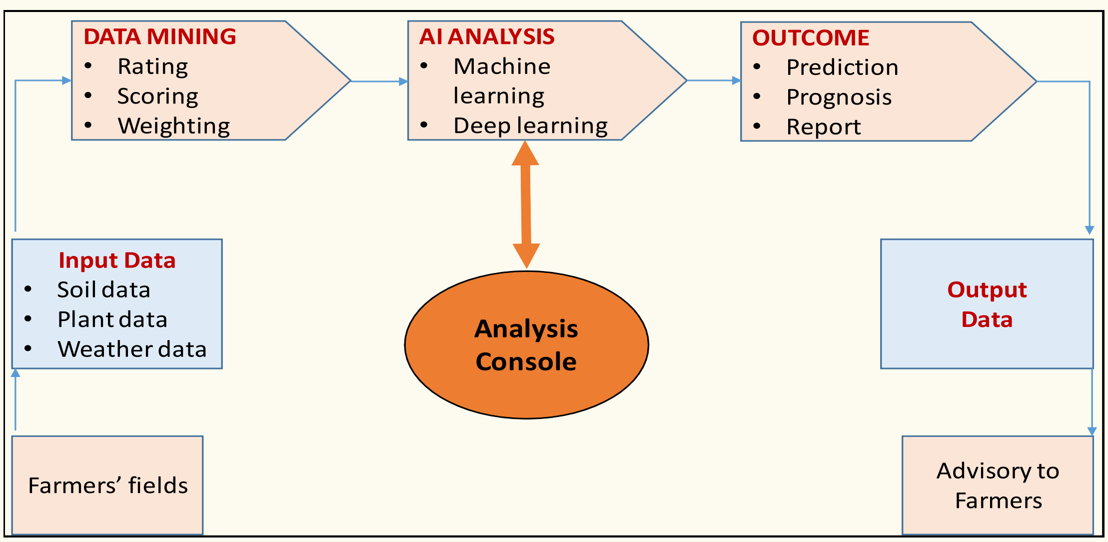


Figure 1: Flow chart of AI in pulse disease management support

fested farms. Important aspects of maintaining crop health include high seed rate of healthy and viable seed, ensuring appropriate drainage and root growth, early sowing to increase yield potential and shallow sowing for quick germination as well as seedling establishment. These methods are partially successful so they should be used in conjunction with resistance and seed treatment. However, the probability of forming severe root rot can vary substantially across a field because several root rot pathogens are intrinsically unevenly distributed on every field. To reduce root rot risk and maintain or improve pulse production throughout the area, new tools like use of partially resistant cultivars as well as pathogen avoidance based on individual field risk assessments would play crucial role in enhancing the efficacy of existing tools like seed treatment as well as early and shallow sowing.

Management of different foliar diseases

Chemical control and host resistance to pathogens have taken centre stage in research and development to combat pulse diseases. There has been a recent shift in pulse disease management practices with an emphasis on identifying, evaluating and integrating components those are specific to location for IDM. In general, IDM adheres to a set of principles. The use of a single component or a mixture of components can successfully mitigate pulse diseases (seed treatment and fungicide). The host plant's resistance, disease modelling for avoiding high risk or disease pressure, chemical use, applying biological control agents and cultural agronomic practices are main components of IDM. Sulphur, on the other hand is extremely effective against foliar fungal diseases like powdery mildews disease. For optimal result, it can be used as protectant at a minimum of 7–14 days intervals. Garlic contains high amount of sulphur, which can be added to a homemade spray by crushing a few cloves in water. It is used as an organic fungicide when pathogens first appear and can also be used again if needed. In case of *Ascochyta* blight disease information of weather conditions is necessary for disease development and their management. Cloudy weather and frequent rainfall are the most important factors for disease development.

The new generation technologies

In present scenario, Precision Agriculture (PA) is gaining popularity to boost yields in a sustainable manner. PA is a broad word that encompasses all approaches used to improve the accuracy and control of agricultural management. Tractor navigation using the Global Positioning System (GPS), remote sensing, data analytics, robotics, and unmanned aerial and terrestrial vehicles are examples of these techniques. A crucial pillar of PA is early and precise detection of pests and diseases.

The use of Machine Learning Algorithms (MLA) and Image Processing Techniques (IPT) in disease detection and recognition is a new field of study with a lot of promise for solving the challenge of early and accurate pest and disease detection. MLA has been used in various disciplines, including as ImageNet. IPTs are computerised processing and analysis of images acquired by a wide range of sensors, such as visible light cameras, infrared imaging devices and sensors that operate in various bands of the electromagnetic spectrum. Indeed, hyperspectral and spectroscopic techniques have been used to identify crop pests and diseases, which have resulted in a lot of encouraging research. However, hyperspectral equipments are costly and out of reach for most farmers and extension workers. As a result, image processing approaches used in foliar disease recognition utilising visible light (RGB) images have a lot of potential. Plant disease symptoms are usually clearly visible on the affected plant. IPT offers the following benefits:

- The severity of the disease can be evaluated by comparing the size of the deformed or discoloured area to the overall size of the leaf, fruit or flower.
- Monitoring disease progression in plants is crucial for identifying parameters like infection stage and detecting symptoms that are not visible to most humans.
- Using photos of leaves, stems, blooms, and/or fruits, IPTs can be utilised to perform tasks rapidly and precisely to reorganise crop diseases.
- IPTs will also assist researchers in detecting disease resistance properties of new crop cultivars

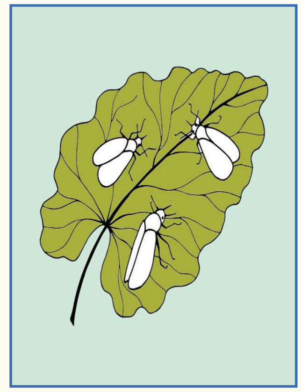
that are being studied in the lab.

- ♦ Obtained information with the help of IPTs can be provided promptly to other people in remote regions in cost effective manner.
- ♦ Accurate diagnosis will result in more cost-effective pesticide application. This would reduce manufacturing costs while also protecting the environment and facilitating accessibility to highly regulated yet profitable markets like the EU.
- ♦ Improved access to human specialists who might be consulted remotely instead of actually visiting individual farms in person.

Conclusion

Pulse crops, including annual grain legumes such as field pea, dry bean, lentil, and chickpea has been developed as crucial part of agricultural cropping system. Intensity of seedling blight, damping-off, wilt, root rot and early ripening of pulse crops is becoming more frequent among many areas, resulting in lower production. A concise overview of root and foliar diseases with a focus on the root rot complex and its management was presented in this article. It has been highlighted that IPM tools are necessary to enable effective and sustainable disease management for root rot and foliar diseases. Several pathogens under this disease complex can be reduced by seed-treatment with fungicides, however integrating many fungicides may be necessary to protect seedlings against the pathogen complex found in most of the commercial fields. Although partial resistance to several pathogens has been established in the complex, it is not yet available in commercial cultivars. Root rot management has been demonstrated to benefit from cultural approaches such as diverse agricultural rotations and early and shallow sowing. In the long run, biocontrol agents might be useful. Improved techniques of identifying and quantifying pathogen inoculum in particular fields being developed by new generation technologies may assist producers in avoiding high-risk fields.

Whitefly: An Emerging Pest of Vegetable Crops



[1]U.S Nayak, [2]C K Das and [3] P. Pati

Vegetable based farming is rapidly emerging as one of the important production systems in India as this enterprise produces comparatively higher income in a shorter period of time than any other agricultural crops. Therefore, intensive vegetable farming has been increasingly adopted by a large number of small and marginal farmers as a viable livelihood option. With increased public awareness on health and nutrition, changing dietary patterns of the people and high population growth, the demand of vegetables is escalating. To maximise production and productivity of vegetables, many new high yielding varieties and hybrids have been adopted along with agronomic practices like higher fertilizer and insecticide application and frequent irrigation, which has aggravated the insect pest incidence in vegetable eco-system and a shift in pest status has been realized over the years. Vegetables being more succulent and rich in nutrients are usually prone to heavy infestation of insect pests, which not only reduces the crop yield but also impairs its quality. Among the pests, whitefly has emerged as an important insect pest in vegetables and caused extensive economic damage. Earlier this pest was considered as a minor pest of vegetables but due to some favourable ecological conditions and inappropriate human interventions, it has attained the status of major pest.

Whiteflies, *Bemisia tabaci* (Genn.) (Hemiptera: Aleyrodidae) are minute insects that occur in groups on the underside of leaves and fly away even with the slightest disturbance. They lay eggs underside leaf surface, usually on younger leaves. The eggs hatch in 8 to 10 days and there are four immature or nymphal stages. First instar nymphs are called crawlers that crawl a short distance before settling to feed on plant tissue. Second and third instar nymphs are stationary and remain attached to the leaf surface where they feed until developing into the fourth and final nymphal stage. These fourth instar nymphs stop feeding, pupate and emerge from the pupae case as fully developed adults. Whiteflies utilize haplo-diploid reproduction method, in which fertilized eggs give rise to females, and males

Senior Scientist, Regional Research and Technology Transfer Station, Ranital, Odisha-756111,
Odisha University of Agriculture and Technology, Bhubaneswar, Odisha
Corresponding author email: usnayak74@gmail.com

are produced from unfertilized eggs. Thus all male offspring inherit only the maternal genome, whereas female offspring inherit genetic material from both parents. The male: female sex ratio in whitefly populations is regulated through an increased production of females when males are highly abundant. Conversely more male offspring are produced when males are in short supply, owing to the greater number of unfertilized eggs, thereby increasing the number of males, which in turn results in more female offspring being produced.

They damage the crops by direct feeding through sucking the cell sap using piercing and sucking mouthparts and excrete honeydew that promotes the growth of sooty mold on leaves and different plant parts. Both nymphs and adults feed on lower surface of the leaves causing reduction in growth and vigour of plants and deformation of young leaves. In severe case of infestation, the plants get dried up and eventually die. However,they cause maximum damage through transmission of important viral diseases in a number of eco-

Little Leaf in brinjal

nomically important crops. During the past few years, the importance of *B. tabaci* as a vector of plant viruses has continued to increase dramatically and it is now considered as the most important invasive insect and vector of plant viruses. The emergence of whitefly and the transmission of viral diseases is associated with changes in cropping pattern, cropping practices, climatic condition, increased global movement of planting materials and intensive use of insecticides. More than 110 viral diseases are transmitted by whitefly in both field and horticultural crops and 90 % of white-

Leaf curl in Tomato

fly transmitted viruses are begomoviruses, the most rapidly evolving virus genus infecting plants. The common viral diseases transmitted by whitefly in vegetables are leaf curl and yellow leaf curl in tomato, leaf curl in chilli, YVMV in okra, apical leaf curl virus in potato, little leaf in brinjal, yellow mosaic in french bean and country bean and many viral diseases in cucurbits and cow pea. This pest is rapidly widening its host range and has started inflicting heavy damage in many vegetables. Development of new biotypes (B and Q biotype) and introduction of an allied species i.e. spiralling white fly (*Aleurodicus disperses*) has intensified the damage level and offered new challenge to farmers and researchers. Biotype B, also known as *Bemisia argentifolii* is a serious pest in many vegetables including cucurbits, tomato, eggplant, capsicum and beans. It has a high reproduction rate, a short generation time, wider host range and has the ability to quickly develop resistance against many insecticides. Both the B- and Q-biotypes appear to have the ability to detoxify new insecticides like neonicotinoids and insect growth regulators like pyriproxyfen. While the

YVMV in Okra

B-biotype has better virus transmission capacity, the Q- biotype has the higher ability to develop resistance against insecticides. Similarly, the spiraling whitefly, *Aleurodicus dispersus*, a native of the Caribbean and Central America accidentally introduced to India has widened its host range infesting many vegetables, fruits, ornamental and field crops. It damages plants by sucking the cell sap, excreting honeydew and white waxy flocculent substance which affects the photosynthesis of the crop and ultimately the crop yield. It is difficult to manage this pest with conventional insecticides as they are covered with heavy waxy flocculent material and its ability of rapid dispersal.

Reasons for outbreak of the pest:

- Climate change favours the outbreak of whitefly by providing a conducive climatic condition as hot and dry climate is highly congenial for the multiplication of this pest. Many research findings reveled that population build up of white flies has positive correlation with maximum temperature and negative relationship with evening RH.
- Frequent application of insecticides, particularly of synthetic pyrethroid groups to manage some major pests like tomato fruit borer, brinjal shoot and fruit borer, okra shoot and fruit borer, cucurbits fruit fly etc. led to secondary resurgence of white fly in these crops.
- Similarly, repeated application of synthetic pyrethriods and their various combination products often at under doses to control white fly and its transmitted viral diseases cause primary resurgence of this pest.
- Indiscriminate application of insecticides resulted in widespread killing of natural enemies of white flies.
- Rapid development of resistance to many insecticides including the new generation ones.

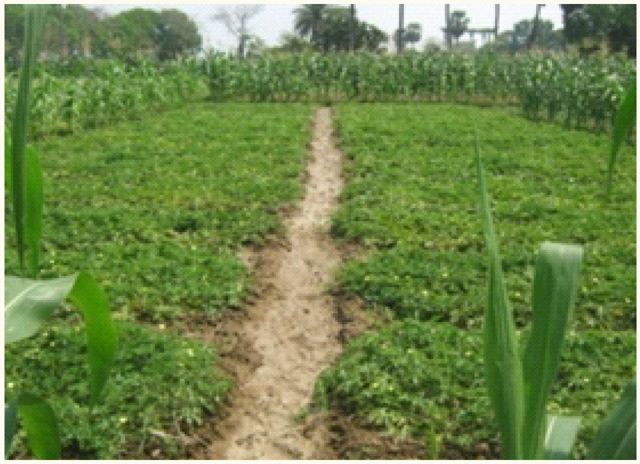
Management of Whiteflies:

Whiteflies cannot be effectively controlled with sole application of insecticides and alternative strategies need to be developed to combat its infestation as well as the viruses it transmits. They are difficult to manage once their populations have reached higher levels and further repeated applications of insecticides

can lead to development of high level of resistance. The best strategy is to adopt IPM approach by judiciously integrating all the available technologies to bring down population of whiteflies below the economic threshold level. In many situations, natural enemies in the crop eco-system can provide adequate control of whiteflies and hence their conservation is of utmost importance for the reduction in insect population. However, the activities of predators and parasitoids are often disrupted due to indiscriminate application of insecticides and ant interference at the honey dew deposition sites. Whiteflies have many natural enemies including the predators like lacewings, pirate bugs, damsel bugs, several lady bird beetles and a number of parasitoids like *Encarsia sp*. which offer a good control under natural environment. This pest is mostly attracted to yellow colour and this insect behaviour can be exploited for pest management by placing some yellow sticky traps in the vegetable fields. Commercial yellow sticky traps are available in the market but to reduce the cost, some yellow coloured earthen pots or aluminum sheets can be used by smearing some sticky substances at their outer surface. Periodic cleaning is essential to remove insects and dust particles from the boards and maintain the sticky surface. Similarly, reflective plastic mulches can repel whiteflies, away from the crop fields thus reducing their probability of alighting (landing) on host plant and subsequent virus transmission. Large number of weeds act as alternate hosts of whitefly and reservoir of viral pathogens, hence clean cultivation around the crop area can reduce the pest infestation.

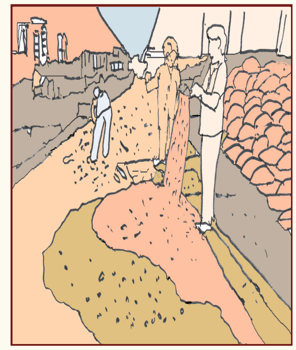
The following IPM module needs to be popularized in farmers' field:

- Seed treatment with imidacloprid 600 FS @ 5 ml/ kg of seed to provide protection to crop during early stages of growth. Raising seedlings in insect-proof (50–64 mesh) nylon net houses and net tunnels or poly house and poly tunnels prevents seedling infestation and subsequent viral transmission.



- Barrier cropping with two rows of maize around crop field minimizes the chance of pest migration from one field to other as this insect is not a swift fliers and cannot fly longer distance. Whiteflies are less likely to remain in a mixed/ inter cropping system in comparison to pure stands. Intercropping also provide habitats for natural enemies that can contribute to natural reduction in pest population. Hence, intercropping of onion or garlic or coriander with tomato, brinjal and chilli can minimize the population build up of white flies.
- As white flies are attracted to yellow colour , installation of yellow sticky trap @ 25/ ha slightly above or at the canopy level will attract and trap the insects.
- Foliar application of entomopathogenic fungal formulations (biopesticides) like *Beauveria bassiana* and neem based pesticide (300 ppm azadirachtin) @ 1 litre/ ha will check the population build up of the pest.
- If the pest population crosses the economic threshold level (ETL), alternate spray of systemic insecticides like flonicamid 50 WG @ 150 g/ ha, thiomethoxam 25 WG @ 200 g/ ha, imidacloprid 17.8 SL @ 250 ml/ ha, diafenthiuron 50 WP @ 300 g/ ha and buprofezin 25 SC @ 750 ml/ ha may be done to prevent the pest from causing economic damage. Same insecticides or insecticides of similar chemistry should not be used repeatedly for delaying the resistance development process.

Fair Market Access and Remunerative Prices Through e-NAM



Dinesh Chand Meena and Purushottam Sharma

In India, the regulation of agricultural marketing was overseen by the state Agricultural Marketing Directorate/ Board through wholesale markets established under the APMC Act. However, this system faced some challenges due to regulatory mechanisms and restrictions on trading agricultural products. To address these issues, the Government of India implemented several reforms in the sector through the Model Act 2003 and APLM Act 2017. However, the agricultural marketing system in India has historically faced problems such as limited storage, grading, processing, and transportation facilities, non-transparent trading and price discovery, a lack of quality awareness among farmers and traders and insufficient marketing information networks. As Indian agriculture has become more market-oriented and commercialised, new opportunities for effective market formats, such as electronic markets, warehousing, FPOs and contract farming, have emerged. The Government of India has responded to these changes by launching the National Agriculture Market (e-NAM), an online trading platform for agricultural commodities to provide fair and transparent pricing to farmers and create a unified national market. This electronic trading platform connects various Agricultural Produce Market Committee (APMC) mandis. The Small Farmers Agribusiness Consortium (SFAC) is responsible for implementing e-NAM under the guidance of the Ministry of Agriculture and Farmers' Welfare, Government of India. The e-NAM is not a separate marketing structure but a tool to establish a nationwide network of physical mandis that can be accessed online. While it is a virtual marketplace, it is backed by a physical Mandi.

National Agriculture Market (e-NAM) aims to utilise the current mandi infra structure and implement an online trading platform that allows buyers outside the state or Mandi to participate in local trading. e-NAM will improve farmers' digital access to multiple markets, buyers and service providers while promoting transparency in business transactions, ultimately leading to fair prices. Its goal is to streamline the marketing and transaction procedures to ensure uniformity and promote the efficient functioning of all markets. Providing online access to more buyers and markets is expected to help in real-time price discovery based on demand-supply situation, ensure transparency in auction process and eliminate information asymmetry among supply chain players, and thus expected to create better marketing opportunities for farmers and sellers. Additionally, this platform will offer online payment options for added convenience and establish quality assaying systems to promote informed buyer bidding. The overarching vision is to create a consistent and efficient system for agriculture marketing, which involves simplifying procedures across integrated markets.

Progress of e-NAM

The Government of India launched e-NAM on 14th April 2016, inspired by the success of the e-mar-

ICAR-National Institute of Agricultural Economics and Policy Research, New Delhi-110012
Corresponding author email: Dinesh.Meena@icar.gov.in

ket in Karnataka state. Since its launch seven years ago, e-NAM has made significant achievements. It currently links 1361 markets or Agricultural Produce & Livestock Market Committee (APMC) from 23 states and 4 UTs. The e-NAM platform has registered 1.76 crore farmers, 2.44 lacks traders, and 1.09 lacks Commission agents, with 2761 FPOs and 79 service providers. To achieve the desired objective and success of e-NAM, it is crucial to link all Mandis with e-NAM and ensure the active participation of stakeholders in e-NAM trading. Table 1 shows that Tamilnadu, Rajasthan, Gujarat, Madhya Pradesh, Uttar Pradesh and Maharashtra account for more than 60% of the registered mandis on the e-NAM portal. Among these states, Rajasthan has the highest number of registered traders (34.36% of total registered traders) and issuance of Unified licenses (51%), followed by Uttar Pradesh. Thus, Rajasthan has successfully linked mandis and encouraged stakeholder participation, securing the first position. In the Country, transactions worth Rs. 2.50 lakh crore have been made through e-NAM, with about 6.9million metric tonnes. The e-NAM platform facilitates trading 209 agricultural commodities, including food grains/cereals, oilseeds, fruits, vegetables, spices, and Miscellaneous. It connects surplus production regions with deficit regions, leading to better market competition and higher prices for farmers' produce. Buyers can also access products across markets, making it a win-win situation for all stakeholders. The 1800-270-0224 is the call center number for farmers, traders, and FPOs seeking information about e-NAM, logistics, and transportation facilities.

On July 14th, 2022, the MoA&FW, GoI, launched a "platform of platforms" (PoP) under e-NAM to establish a digital ecosystem in agriculture. The PoP involves 79 service providers from different segments of the agricultural value chain, which offer various value chain services, like logistics, cleaning, grading, sorting & packaging, assaying, warehousing, agricultural input service, technology-enabled finance & insurance service, and information dissemination. This initiative allows farmers, traders, FPOs, and other stakeholders to easily access a variety of goods and services across the agricultural value chain through a single window, providing them with more options. A state must meet three important requirements for proposing Mandis for "Plug-In" to e-NAM. Firstly, the state's APMC Act must have an explicit provision for e-auction or electronic trading as a means of price discovery. Secondly, a single trading license should be valid throughout the entire state or UT. Finally, there must be a single-point levy of market fees across the entire state or UT. Various modules have been introduced to improve the efficiency of e-NAM. Here is the list of some important modules.

i. Integration of e-NWR-based trade with e-NAM

ii.FPO module and Farm Gate Integration

iii.Integration with Agmarknet, Kisan Rath, Kisan Suvidha & Umang platforms

iv.Inclusion of Banking Partners on e-NAM

v.Part Payment Feature

Table.1: Major State-wise e-NAM profile (as of June 2023)

Major States	Mandis registered(%)	Registered Traders (%)	No. of Unified licenses issued (%)
Andhra Pradesh	2.42	1.47	2.18
Gujarat	10.58	4.08	6.05
Haryana	7.94	6.53	0.02
Madhya Pradesh	9.99	9.20	0.67
Maharashtra	8.67	8.96	0.00
Odisha	4.85	3.43	5.08
Punjab	5.80	1.10	0.00
Rajasthan	10.65	34.36	50.97
Tamil Nadu	11.54	3.79	3.71
Telangana	4.19	2.43	3.60
Uttar Pradesh	9.18	15.90	23.58
Others	14.18	8.76	4.15

Source: *Compiled from the e-NAM portal*

Marketing Process of Agri-Produce through e-NAM

When agricultural produce is brought to the APMC Mandi, it goes through several stages before leaving the market. The process begins with farmers or sellers registering their vehicles and themselves on e-NAM to bring the com-

modity for sale. The commodity is then weighed, either lot-wise or vehicle-wise and a sample is drawn for quality testing. Next, the auction process takes place, and if the commodity is not sold, the farmers or seller takes the items back or to the warehouse. However, if the auction is successful, the buyer proceeds to the post-trade exit with the commodity.

Registering on e-NAM is free of charge. However, it is mandatory to provide personal details such as name, sex, address, date of birth, mobile number and bank information like a passbook or cheque leaf document. Any government-issued identity proof can be used for this purpose. Farmers can register themselves through the following ways, viz. Via e-NAM Portal- http://www.enam.gov.in; through Mobile Application, and through Mandi Registration (At Gate Entry)

Workflow of trading in APMC for farmers/sellers

Step1: Entry gate	The vehicle must register the crop or product being brought to the Mandi for sale. Additionally, there should be prompt registration for farmers and sellers.
Step 2: Weighted	Once registered, the farmer or seller must weight their vehicle or product.
Step 3: Quality assaying	Before selling their products at the Mandi, the seller must ensure that they undergo a quality check.
Step 4: e-Auction	In order to sell their products or crops, the seller is required to participate in an e-Auction. If the seller is not interested in the sale, they must lead themselves to the exit gate after settlement.
Step 5: Exit gate	After the trade settlement, the seller is required to exit the Mandi gate with a post-trade slip. However, if the product is not sold, the seller must also leave with a product return slip.

Workflow of online trading in APMC for traders/buyers

Step1:e-NAM registration	In order to participate in e-NAM, traders/buyers must first register on the portal. Once registration is complete, they can proceed to login.
Step 2: Trading/ bidding	On the new bid listing page, traders and buyers can review the available commodities for bidding. Once they select the desired commodity, they can begin the bidding process. The trader can access information on the commodity market amount and the last and previous bid amounts. To place a bid, the trader enters the desired amount in the new bid column.
Step 3: Other options for the buyer in e-NAM	Traders/buyers can view the trade history and access information regarding security/margin deposit details, as well as the pending amount against invoices raised.

Workflow of online trading in APMC for Commission Agent (CA)

Step1:e-NAM registration	To participate in the e-NAM Portal, CA needs to register first. Once registered, they can log in and access the portal.
Step 2: Lot Consent	CA can view a list of lots, consent and pending consent.
Step 3: Dashboard	On his login dashboard, CA can access information on the arrival of various commodities, including their weighted and bid rate details.

Quality assessment of produce: Product quality is determined and certified based on specific parameters set by the Directorate of Marketing & Inspection (DMI), which has standardised quality parameters for 193 commodities. The e-NAM platform offers harmonisation of quality standards for agricultural produce and provides the quality testing infrastructure in every market to allow informed bidding by buyers without charging sellers any fees. The product is categorised as premium, average, or below average quality based on its respective testing range, which falls within range I, II, or III. The number of quality parameters tested for assaying varies depending on the commodity, with a focus on physical parameters. Chemical testing, such as oil content, may be performed for some commodities before certification results are published on e-NAM. Generally, products are expected to be clean, wholesome, and reasonably uniform in size, shape, and colour, with no obnoxious smell or fungus infestation. The essen-

Workflow of online trading in APMC for traders/buyers

Step1:e-NAM registration	In order to participate in e-NAM, traders/buyers must first register on the portal. Once registration is complete, they can proceed to login.
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Step 3: Other options for the buyer in e-NAM	Traders/buyers can view the trade history and access information regarding security/margin deposit details, as well as the pending amount against invoices raised.

tial quality parameters, including moisture (% by weight), foreign matter (% by weight), other edible grains (% by weight), damaged grains (% by weight), weevil-led grains (% by count), admixture (% by weight), immature &shrivelled (% by weight), etc., are tested to assign a quality range for each product. Optional quality parameters like uric acid and aflatoxin may be analysed based on buyer-seller agreement. Farmers may sell their produce on e-NAM without assaying, but this may not result in a better price.

Time required to sell produce

The e-NAM digitally records all arrivals and assigns unique LOT IDs, which can be tracked from mobile until it is sold. This digitalisation aims to reduce the transaction time in the e-NAM Mandi. However, the completion time of the transaction depends on other factors like the volume of arrivals of that particular Mandi and the season.

Payment for sold products

After finalising the sale agreement, traders must make online payments directly to farmers' bank accounts using various online payment methods like RTGS/NEFT, Debit Cards, and Internet banking. Furthermore, the introduction of the Unified Payment Interface (UPI) through BHIM has made the payment process for farmers more convenient and reduced the time taken for payment realisation.

Benefits of e-NAM

The e-NAM platform is a great tool for all stakeholders involved in the agricultural industry, including farmers, traders, buyers, processors, and exporters. It offers transparent bidding processes that help farmers and sellers secure better prices for their products and gain access to buyers from various markets. This, in turn, increases their choices and negotiating power when selling at the Mandi. The e-NAM also provides real-time information on prices and arrivals at nearby mandis, reduces transaction costs for buyers and sellers, and provides an online payment system that reduces payment risks and ensures prompt payments to farmers. Furthermore, bidding on quality parameters of commodities ensures that farmers receive better prices for high-quality produce. Farmers can choose to accept either local or online offers, and all transactions are recorded in the local Mandi's and APMC Mandi's books. The e-NAM mobile app features a GPS-based mandi locator function that helps farmers easily locate and reach their nearby e-NAM Mandi to sell their agricultural produce. Additionally, before visiting the Mandi, farmers can access the prevailing commodity prices and arrival information of both e-NAM and non-e-NAM Mandis on the e-NAM mobile app. The e-NAM website and portal are available in 12 languages, including English, Hindi, Bengali, Marathi, Gujarati, Tamil, Telugu, Punjabi, Odiya, Dogri, Malayalam, and Kannada.

According to the researchers' findings, farmers have noted reduced marketing costs since implementing e-NAM. Studies observed that the prices offered through e-NAM are comparable to those found in other marketing channels. However, participating in e-NAM has been beneficial due to the absence of additional charges. Online trading has eliminated the 2% commission charged by traders and other hidden costs while ensuring accurate weighing. Below are the

Studies showcasing advantages of e-NAM/ e-auctioning/e-tendering	References
Increased farmers income	Roy et al., 2017; Kumar et al., 2020; Singh et al., 2021; Swain et al., 2022
Increased marketing efficiency	Chengappa et al., 2012
Increased competitiveness and market integration	Mishra and Mishra 2017; Pavithra et al., 2018; Swain et al., 2022
Reduced wastage and consumer prices of products	SFAC, 2015
Increased market revenue, and reduced transaction cost and time	NIAM, 2015; Mustaqquim, 2017; Pavithra et al., 2018
Reduced market intermediaries and traders' monopoly	Mishra and Mishra 2017; Swain et al., 2022
Improved transparency and reduced imperfection in the marketing system	Chand, 2016; Pavithra et al., 2018
Reduced farmer's dependency on MSP and public procurement	Chand, 2016
Single licensing and single point levy	Dey, 2016; Chand, 2016
Increased trade expansion	Roy et al., 2017

summarised studies that showcase the advantages of e-NAM/e-tendering.

Way forward

The electronic National Agriculture Market (e-NAM) has the potential to facilitate price discovery and enhance marketing efficiency by reducing information asymmetry between farmers and traders, decreasing reliance on intermediaries such as commission agents, and lowering transaction costs and time. e-NAM offers an opportunity to improve marketing efficiencyby improving transparency, competitiveness, and market integration. However, achieving the desired outcomes of e-NAM and expanding trade under it requires awareness creation and capacity building for stakeholders, as highlighted in various studies. In addition, for optimal functionality, e-NAM must be seamlessly incorporated with Artificial Intelligence and the Internet of Things (IoT) in order to deliver prompt and accurate information and analytics to various various stakeholders at any time and place.

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In House Production, Publication Cell, Directorate of Extension
Krishi Vistar Sadan, Pusa, New Delhi - 110012