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PRECISION NITROGEN MANAGEMENT IN CEREAL CROPS

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Introduction:

Cereals are the major source of food and fodder. Total cereal production of world and India is 2400 and 230 Million tones, respectively during 2015 (Anon, 2017). Nitrogen is major nutrient required for production of cereals. It play vital role for synthesis of chlorophyll and protein. Nitrogen use efficiency is very less (25-30%), because it is lost very easily through volatilization and leaching so precision nitrogen management is required. Following tools are used for precision nitrogen management in cereals.

Tools of Precision Nitrogen Management

Leaf colour chart	Crop canopy sensor
Site specific nutrient management	Crop simulatin model
Chlorophyll meter	Controlled release fertilizers

Leaf Colour Chart

Leaf colour charts (LCC) offer substantial opportunities for farmers to estimate plant nitrogen (N) demand in real time for efficient fertilizer use. Indian farmers generally apply fertilizer N in a series of split applications, but the number of splits, amount of N applied per split and the time of applications vary substantially

How to use the LCC?

- ✓Select at least 10 disease-free plants
- ✓Select the topmost fully expanded leaf and compare the leaf colour with the colour panels of the LCC and do not detach or destroy the leaf
- ✓Measure the leaf colour under the shade of your body
- ✓Determine the average LCC reading for the selected leaves
- ✓If more than five out of ten leaves read below a set critical value apply nitrogen fertilizers immediately to avoid yield loss

Advantages of Leaf colour chart

- ➢The LCC is a cheap
- ➢Farmers can easily use the Leaf colour chatrs to qualitatively assess foliar N status and adjust N topdressing accordingly
- ➢It helps to manage N for large area leading to improved fertilizer N use efficient

Jayanthi *et al.* (2007) noticed that significantly higher grain yield of rice under basal application of 20 kg N ha^{-1} + 20 kg N ha^{-1} based on bi-weekly LCC reading as compared to farmer's practice. Similarly, N application at LCC value 4 gave significantly higher grain yield of rice than other treatments (Rout, 2007 and Debnath and Bandyopadhyay, 2008).

Gajera *et al.* (2014) reported that N application based on LCC value 5 @ 120 kg ha^{-1} in 3 splits gave significantly higher grain yield of wheat compared to other treatments.

Site Specific Nutrient Management

Site-specific nutrient management (SSNM) is the dynamic, field-specific management of nutrients in a particular cropping season to optimize the supply and demand of nutrients according to their differences in cycling through soil-plant systems.

SSNM aims to increase profit through

- ❖ High yield.
- ❖ High efficiency of fertilizer use.
- ❖ Providing a locally-adapted nutrient best management practice tailored to the field- and season-specific needs for a crop.

Stalin *et al.* 2008 and Peng *et al.*, 2010 reported that application N @ 125 kg ha^{-1} and 133 kg ha^{-1} through SSNM gave significantly higher grain yield of rice as compared to other treatments, respectively.

The highest grain yield of rice was observed in NPK treatment, which gave 9.0, 34.4 and 50.7 % higher yields than those of NP, NK, and PK, respectively (Nath *et al.*, 2013).

Chlorophyll Meter

- ✓ It is a simple, quick and non destructive in situ tool for measuring relative content of chlorophyll in leaf that is directly proportional to leaf N content.
- ✓ The chlorophyll present in the plant is closely related to the nutritional condition of the plant.
- ✓ Higher SPAD value indicates a healthier plant. A decrease in the SPAD value indicates a decrease in the chlorophyll content and nitrogen concentration; it is show the lack of nitrogen available in the soil. This problem can be solved by adding fertilizer to the soil.

Application of chlorophyll meter

- Improve nutrient management.
- Study the performance and effect of fertilizer.
- Detect and study environmental stressors.
- Checking the nutritional condition of plants.

Measuring SPAD values in the field

- SPAD readings are taken at 9-15 day intervals, starting from 14 DAT for transplanted rice and 21 DAS for wet direct seeded rice, Periodic readings continue up to the first (10%) flowering.
- The youngest fully expanded leaf of a plant is used for SPAD measurement.
- Readings are taken on one side of the midrib of the leaf blade.
- A mean of 10-15 readings per field or plot is taken as the measured SPAD value.
- Whenever SPAD values fall below the critical values, N fertilizer should be applied immediately to avoid yield loss.

Advantages of Chlorophyll Meter

- ➢ The chlorophyll meter is faster than tissue testing for N.
- ➢ Samples can be taken often and can be repeated if results are questionable.
- ➢ Chlorophyll content can be measured at any time to determine the crop N status.
- ➢ The chlorophyll meter allows “fine tuning” of N management to field condition.
- ➢ The Chlorophyll Meter would also help people who are not highly trained to make N recommendations.

Hussain *et al.* (2000) observed that similar rice yields were produced with chlorophyll meter with saving of 30 kg N ha^{-1}.

The significantly higher grain yield of rice was observed when 90 kg N ha^{-1} was applied in 3 equal splits when SPAD reading was < 37.5 (Singh, 2008).

Ghosh *et al.* (2013) found that application of N @ 88.3 kg ha^{-1} when SPAD value was 36 gave significantly higher grain yield of rice compared to other treatments.

Crop Canopy Sensor

Crop canopy sensors can be used to estimate crop growth in a population or community rather than individual plant or leaf. It was more efficient and suitable for large scale applications than leaf sensors. (Xue and Yang)

Crop canopy sensor are-

(i) Green seeker (ii) Crop circle

Green Seeker`

Green seeker is emerging as a potential tool for efficient nitrogen management through monitoring crop growth with remotely sensed indices like NDVI (Normalized difference vegetation index).

Crop circle sensor

The crop circle sensor is also active and operates under the same principle as that of the green seeker sensor, however the visible light produced by this sensor is called "yellow" by the manufacturer but has also been referred to as the "amber". Therefore, this sensor will be referred to as "amber sensor" and the index calculated will be referred to as "amber index".

Gupta, 2006 reported that use of green shaker save 25-30 kg N ha^{-1} and 68 kg N ha^{-1} without reduction of grain yield of wheat and rice, respectively.

Sapkota *et al.* (2014) observed that application of N @ 154 kg ha^{-1} based on Green shaker gave significantly higher grain yield of wheat compare to other treatments.

Crop Simulation Model

Crop simulation models are quantitative tools based on scientific knowledge that can evaluate the effect of climatic, edaphic, hydrologic and agronomic factors on crop growth and yields.

- *Crop simulation model groups*

1. DSSAT models 2. CERES models 3. WOFOST models 4. Other crop models

Alphen and Stoorvogel (2000) observed that simulation model based application of N save 23 % N and with 3 % increased grain yield of wheat.

Thorp *et al.* (2006) reported that by using simulation model it can be determine that application of 240 kg N ha^{-1} in corn gave maximum marginal net return.

Controlled Release Fertilizer

A **controlled-release fertilizer** (**CRF**) is a granulated fertilizer that releases nutrients gradually into the soil.

Terms sometimes used synonymously

(i) Slow-release fertilizer (ii) Delayed-release fertilizer

Three general categories of controlled release fertilizer?

(i) Uncoated, controlled-release (ii) Coated, controlled-release

(ii) Bio-inhibitors

–Not really "slow-release" but

–Inhibit microbial processes that convert N into plant available forms and Slowly (or relatively slowly) parse N into soil environment

1. Uncoated, slow-release	2. Bio-inhibitors	3. Coated, slow-release
Urea-formaldehyde reaction products Isobutylidene diurea (IBDU) . Inorganic salts	Urease inhibitors Nitrification inhibitors	Sulfur-coated urea Polymer-coated (or Poly-coated) ure Neem coated urea

Jena *et al.* (2003) reported that application of N @ 114 kg ha^{-1} and 76 kg ha^{-1} through urea super granules gave significantly higher grain yield of rice compared to other treatments.

Kumar *et al.* (2013) observed that application of N @ 160 kg ha^{-1} organic matrix entrapped urea gave significantly higher grain yield and straw yield of wheat compared to all other treatments.

Conclusion

Nitrogen is the key element for production of cereals. LCC, SPAD meter, SSNM, crop canopy sensor, crop simulation models and controlled release fertilizers are effective tools of precision nitrogen management. Around 10-25 % nitrogen can save through precision nitrogen management.

Future Line of Work

✓ Need to develop precision nitrogen management strategies in cash crops and oil seed crops.

✓ Need to develop leaf color chart based nitrogen management for other cereal crops.

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RESOURCE CONSERVATION TECHNOLOGIES IN RICE-WHEAT CROPPING SYSTEM: SOLUTION OF MAJOR ISSUES

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Introduction-Nature's have lot of things to give us, but utilization of these things in proper way is totally depend upon human beings, means in which way we uses these resources. It provides us countless resources, which is due to excess use of chemical, pesticides and incorrect method of cultivation techniques, degrading day by day. If we will not conserve these resources, adverse effect of these things will be face by our upcoming generation. Despite use of excess these resources we should also focus on it to how these resources will be conserve by different recent and traditional technologies. Predominant cropping system in India is the Rice-wheat cropping system as both rice and wheat are main staple food for the people of the country. Threat to sustainable food production has resulted due to the continued adoption of exhaustive rice-wheat cropping system. In order to address the problems like stagnant productivity, increasing production costs, declining resource quality, receding water table and increasing environmental problems alternative technologies are the major drivers. Now various resource conservation technologies are Laser land-levelling, direct seeded rice (DSR), Zero tillage (ZT), furrow-irrigated raised-bed system (FIRBS) *etc*. have been developed to conserve resources without reduction in yield.

Zero tillage- Zero tillage (also called No-till farming or direct drilling) is a way of growing crops or pasture from year to year without disturbing the soil through tillage. No-till is an agricultural technique which increases the amount of water that infiltrates into the soil, the soil's retention of organic matter and its cycling of nutrients. In many agricultural regions, it can reduce or eliminate soil erosion. It increases the amount and variety of life in and on the soil, including disease-causing organisms and disease organisms. The most powerful benefit of no-tillage is improvement in soil biological fertility, making soils more resilient. Farm operations are made much more efficient, particularly improved time of sowing and better trafficability of farm operations. Advantages of zero-tillage:

(a) enhance production stability and yield (4-10%), **(b)** lower production costs (Rs. 2000-3000 /ha), **(c)** reduction of CO_2 emission, **(d)** reduction in fuel consumption, **(e)** lower soil erosion, **(f)** increase soil quality, **(g)** save water, (h) increase biological activity, **(i)** reduce health hazard by avoiding crop residue burning, **(j)** enhancement of water use efficiency, **(k)** reduction of the incidence of weeds such as *Phalaris minor* in wheat.

Laser land leveling- As per studies, a significant (20-25%)amount of irrigation water loss during its application at the farm due to poor farm design and unevenness of the fields. This problem is more pronounced in the rice field. Fields that are not level, have uneven crop stand, increased weed burden and uneven maturing of crops. All these factor leads to reduction in yield and poor grain quality. Laser land leveling is leveling the field at certain degree of desired slope using a guided laser beam throughout the field. Unevenness of the soil surface has significant impact on the germination, stand and yield of crops. Farmers also recognize this and therefore devote considerable time resources in leveling their field properly. However, traditional methods of leveling are cumbersome, the time consuming as well as expensive. Benefits of laser land leveling are:

(a) saves 25-30% water, **(b)** improves crop establishment and improve yields, **(c)** reduce weed problems, **(d)** improve uniformity of crop maturity, **(e)** decrease the time to complete tasks, **(f)** reduce the amount of water require for field preparation.

Direct seeded rice- Transplanted rice has deleterious effects on the soil environment for the succeeding wheat and other upland crops. Direct seeded rice which removes puddling and drudgery of transplanting the young rice seedlings provides an option to resolve the edaphic conflict and enhance the sustainability of rice-wheat cropping system. Puddling requires lots of scarce water at a time when there is little water in the reservoirs, destroys soil structure and adversely affects soil productivity. DSR overcomes the problem of seasonality in labour requirement for rice nursery raising and transplanting operations. Non-development of ground water in *kharif*, late onset of monsoon and drudgery of operations often delays rice transplanting which leads to late vacation of fields, forcing farmers to plant wheat after the optimum sowing time. DSR facilitates timely establishment of rice and succeeding winter crops. Unlike puddle fields, DSR fields do not crack and thus help save irrigation water. Surface retained residue serve as physical barrier to emergence of weeds, moderate the soil temperature in summers and winters, conserve soil moisture, add organic matter and nutrients to the soil on decomposition. Rice can be directly seeded either through dry or wet (pre-germinated) seeding. Dry seeding of rice can be done by drilling the seed into a fine seedbed at a depth of 2-3cm. Wet seeding requires levelled fields to be harrowed and then flooded (puddling). The field is left for 12-24 hours after puddling, then germinated seeds (48-72 hrs) are sown using a drum seeder. Seed can be broadcast for either dry or wet seeding, but manual weeding is more difficult. Indeed, weed management is a critical factor in direct seeding. Timely application of herbicides (timing is dependent on the method of seeding) and one or two hand weedings provide effective control. Advantages of DSR:

(a) avoids repeated puddling, preventing soil degradation and plough-pan formation, **(b)** facilitates timely establishment of rice and succeeding crops as crop matures 10-15 days earlier, **(c)** saves water by 35-40%, reduces production cost by Rs 3000/ha, and increases yields by 10%, **(d)** saves energy: labour, fuel, and seed, **(e)** Solves labour scarcity problem and reduces drudgery of labours.

Furrow irrigated raised based system (FIRBS)- This method has been evolved to economize irrigation water in which raised beds of prepared to accommodate 2 or 3 rows of wheat between 2 furrows. The irrigation is done only in furrows. Thus about half of irrigation required may be saved by this method without any loss of productivity of crop. The wheat yield has been found to be higher than conventional method of wheat sowing. A machine has been developed to make raised bed and sowing of wheat simultaneously has been developed for this purpose. This method helps in economizing water required by the crop besides giving better germination. Advantages of the FIRBS:

(a) Management of irrigation water is improved is simpler, and more efficient. On an average it uses, 30% less water than flat bed methods and improves crop yields by more than 20%,

(b) FIRB planting saves 30% to 50% wheat seed compared to flat bed planting, **(c)** better upland crop production is possible in the wet monsoon because of better drainage, **(d)** fertilizer efficiency can be increased because of better placement including top dress applications, **(e)** wheat seed rates are lower, plant stands are better, **(f)** better tillering, increased panicle/ear length and bolder grain.

System of Rice Intensification (SRI) - The **System of Rice Intensification** (**SRI**) is a methodology aimed at increasing the yield of rice produced in farming. It is a low water, labor-intensive, method that uses younger seedlings singly spaced and typically hand weeded with special tools. It was developed in 1983 by the French Jesuit Father Henri de Laulanié in Madagascar. However full testing and spread of the system throughout the rice growing regions of the world did not occur until some years later with the help of Universities. SRI is a combination of several practices those include changes in nursery management, time of transplanting, water and weed management. Its different way of cultivating rice crop though the fundamental practices remain more or less same like in the conventional method; it just emphasizes altering of certain agronomic practices of the conventional way of rice cultivation. All these new practices are together known as System of Rice Intensification (SRI). SRI is not a fixed package of technical specifications, but a system of production with four main components, *viz*., soil fertility management, planting method, weed control and water (irrigation) management. Several field practices have been developed around these components. Advantages of SRI:

(a) it reduce excess requirement of water which is main problem in rice grown by conventional method, **(b)** it reduces chance to emerge weed because of plant to plant distance are maintained, **(c)** intercultural operations are easy to carried out in field, **(d)** by reducing the application of agrochemicals in rice production, the resulting grain has little or no chemical residues, **(e)** lesser chemical input.

Conclusion - Since RCTs provide saving in input-cost, wide publicity including field demonstrations could generate awareness among the farmers about savings in sowing time and other costs in crop production. Zero tillage and bed planting are the major drift from conventional tillage practices, a holistic approach with a completely new set of package of practices need to be evolved, evaluated and popularized. Saving of energy from less tillage and reduced irrigation has strategic benefit for the country as a whole. Thus, wider adoption of RCTs has long run ramifications in terms of conserving natural resources, saving cost on cultivation and improving the climatic conditions in the region.

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HERBICIDE RESISTANCE IN WEEDS AND THEIR MANAGEMENT

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Introduction- Green revolution took place all over the world to provide food for burgeoning human population, which resulted in excessive use of agrochemicals and monoculture practices. In rice-wheat cropping system of India, weeds were controlled by herbicides with higher intensity during green revolution period mostly by Isoproturon for *Phalaris minor* in wheat (Malik and Singh, 1995) which makes the weeds resistant to herbicide. Now, the management of herbicide resistant in weeds is a new challenge because weeds losses the food grains by 33% (Chauhan *et al.*, 2012) on one hand and food production must increase by 70% to fulfil the food grain demand for increasing human population (1.7 billion by 2050 in India) on another hand. Herbicide resistance now has become a world-wide phenomenon continuously in its number and frequency in almost every year. The adequate agronomic management of herbicide resistant in weeds will help in getting food security. There are several ways to control the resistant biota to herbicides in different parts of the world; agronomic management is also one of them, (Johnson, *et al.*, 2009).

Evolution of herbicide resistance in weed species: Herbicides have revolutionized weed control practices all over the world. Farmers preferred herbicides over cultural and mechanical control practices because of time and cost efficiency, easy to apply and fast + effective weed control. Repeated use and strong reliance on herbicides led to evolution of herbicide resistance in weed population especially for herbicides with single mode of action, (Nandula and Reddy, 2012).

Herbicide resistance and tolerance: Herbicide resistance (HR) is the inherited ability of a plant/biotype to survive and reproduce following exposure to a dose of herbicide normally lethal to the wild type. Herbicide tolerance is the inherited ability of a species to survive and reproduce following an herbicide treatment. There was no selection to make the plants tolerant; those plants simply possess a natural tolerance.

$$\text{Resistance index } (LD_{50} \text{ ratio}) = \frac{LD_{50} \text{ value of the resistant population}}{LD_{50} \text{ Value of the susceptible population}}$$

$$\text{Resistance factor } (GR_{50} \text{ ratio}) = \frac{GR_{50} \text{ value of the resistant population}}{GR_{50} \text{ Value of the susceptible population}}$$

Types of herbicide resistance:

Single resistance: It is simply the resistance of a weed species due to its continuous exposure to a herbicide. It could be –

A) **Complete resistance-** In this type of resistant biotypes are not at all affected by the herbicides used at the field rate/recommended dose. Its growth and reproduction continue unabated and as usual even after that herbicide application.

B) **Partial resistance-** In this resistant biotypes receive severe inhibition on their vegetative growth by the herbicide used at the field rate. However, they continue to grow insufficiently and reach to flowering and produce some seeds.

Cross resistance: It is evolved due to continuous use of same or more herbicides having similar mode of action/single resistance mechanism. Example: Common cocklebur resistant to one herbicide (Classic, Chlorimuron) may also resistant to another herbicide (Scepter, Imazaquin) with the same mode of action (ALS-inhibitor). This is known as cross-resistance.

Negative cross resistance: Mechanism by which an individual resistant to one herbicide or a chemical family of herbicides shows higher or increased sensitivity to other herbicides than its natural wild type susceptible population. Example: Atrazin resistant biotype of Echinochloa crussgalli controlled more effectively by Fluzifop-butyl and Sethoxydim, respectively.

Multiple resistance: When resistance to several herbicides results from two or more distinct resistance mechanism in the same plant. Example: *Lolium rigidum* seedlings were identified as having multiple resistances i.e. resistance to both Triazine (Atrazine) and ALS-inhibiting herbicides (Chlorosulfuron) which have two different mode of action with different mechanisms conferring resistance.

Reverse resistance: The situation in which the weed biotypes resistant to herbicides fall susceptible to that herbicide which is not used for a period of long years, and other alternative herbicides used to kill the resistant population.

Causes of HR in weeds:

1. Over reliance on herbicides for weed control due to unavailability of labour and more labour charges
2. Repeated use of same or other herbicides having same mechanism of action
3. Crop monoculture
4. Minimum/zero tillage

Management of HR weeds:

- Use of alternative herbicides
- Herbicides mixture and rotation
- Herbicide selection and application
- Crop rotation
- Tillage practices
- Integrated weed management

Conclusion: Herbicide resistance in weeds can not only be prevented but also controlled by the proper application of agronomic practices *viz.*, crop rotation, herbicide mixture and rotation, tillage, integrated weed management etc. Although herbicides remain the dominant weed control tool, diversification in cropping system and practices can result in less herbicide used and thus reduction in selection pressure for resistance. Even the serious resistance in weed can be managed successfully if farmers are respective to change in their cropping system.

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IRRIGATION SCHEDULING TECHNIQUES FOR EFFICIENT WATER USE PRODUCTIVITY

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Introduction

Water is a vital natural resource for mankind which is depleting at a very fast rate. It is of a great concern and calls for optimal use of water in every sector. Major portion of fresh water is consumed in agriculture. Therefore, a small saving of water in this sector can make a huge difference in conservation agriculture. Proper irrigation scheduling is an important task for any irrigation water management project. Irrigation scheduling is planning when and how much water to apply in order to maintain healthy plant growth during the growing season. It is an essential daily management practice for a farm manager growing irrigated crops. The purpose of irrigation scheduling is to provide needed water to crop at the right time for higher water and yield productivity.

Proper timing of irrigation water applications is a crucial decision to: 1) meet the water needs of the crop to prevent yield loss due to water stress; 2) maximize the irrigation water use efficiency resulting in beneficial use and conservation of the local water resources; and 3) minimize the leaching potential of nitrates and certain pesticides that may impact the quality of the groundwater. Effective irrigation is possible only with regular monitoring of soil water and crop development conditions in the field, and with the forecasting of future crop water needs. Delaying irrigation until crop stress is evident, or applying too little water, can result in substantial yield loss. Applying too much water will result in extra pumping costs, wasted water, and increased risk for leaching valuable agrichemicals below the rooting zone and possibly into the groundwater.

Efficient Irrigation Scheduling aims to supply the crop with enough water to ensure optimum production while minimizing water loss and nutrient leaching. The amount of irrigation water needed is determined by using a criterion to trigger irrigation and a strategy to determine how much water has to be applied to a given crop at any time during the production cycle. In vegetable crops, the most common criterion is soil θ or ψ_m (also called tension or suction); the goal is to avoid crop damage and to ensure that all irrigation water is used by the crop. A schedule to maximize net economic return, which depends also on water price, is less common. Conventional methods for Irrigation Scheduling rely on determination of soil water balance (weather-based method) or on the direct measurement of soil moisture level. The progress in plant physiology research has allowed the design of innovative irrigation scheduling methods based on the monitoring of plant water relations.

Importance of Irrigation Scheduling

Some irrigation water is stored in the soil to be removed by crops and some is lost by evaporation, runoff, or seepage. The amount of water lost through these processes is affected by irrigation system design and irrigation management. Prudent scheduling minimizes runoff and percolation losses, which in turn usually maximizes irrigation efficiency by reducing energy and water use.

You can save energy by no longer pumping water that was previously being wasted. When water supplies and irrigation equipment are adequate, irrigators tend to over-irrigate, believing that applying more water will increase crop yields. Instead, over-irrigation can reduce yields because the excess soil moisture often results in plant disease, nutrient leaching, and reduced pesticide effectiveness. In addition, water and energy are wasted.

The quantity of water pumped can often be reduced without reducing yield. Studies have shown that irrigation scheduling using water balance methods can save 15 to 35 percent of the water normally pumped without reducing yield. Maximum yield usually does not equate to maximum profit. The optimum economic yield is less than the maximum potential yield. Irrigation scheduling tips presented in popular farm magazines too often aim at achieving maximum yield with too little emphasis on water and energy use efficiencies. An optimum irrigation schedule maximizes profit and optimizes water and energy use.

Irrigation scheduling requires knowledge of:

- The soil
- The soil-water status
- The crops
- The status of crop stress
- The potential yield reduction if the crop remains in a stressed condition.

Irrigation Scheduling Approaches

1. Soil moisture depletion approach:

The available soil moisture in the root is a good criterion for scheduling irrigation. When the soil moisture in a specified root zone depth is depended to a particular level (which is different for different crops) it is too replenished by irrigation.

For practical purpose, irrigation should be started when about 50 percent of the available moisture in the soil root zone is depleted. The available water is the soil moisture, which lies between field capacity and wilting point. The relative availability of soil moisture is not same field capacity to wilting point stage and since the crop suffers before the soil moisture reaches wilting point, it is necessary to locate the optimum point within the available range of soil moisture, when irrigation must be scheduled to maintain crop yield at high level. Soil moisture deficit represents the difference in the moisture content at field capacity and that before irrigation. This is measured by taking into consideration the percentage, availability, tension, resistance etc.

This method consists of estimating the change in soil *moisture* over a period as the difference between the inputs (irrigation and rainfall) and the losses [crop evapotranspiration (ET), drainage, and runoff]. The method follows three basic steps:

1) the available water (AW) in the root zone is estimated from soil texture and rooting depth
2) allowable water deficit (AWD) is selected depending on crop species, growth stage, soil water capacity, and the irrigation system's pumping capacity [AWD is the portion (ranging from 40% to 60%) of AW that can be extracted without causing crop damage]

3) Soil water balance is computed each day to assess water deficit; irrigation is needed whenever AWD is exceeded.

Table: Soil, Water and Plant terms used in Irrigation Scheduling

Term	Definition
Field Capacity (FC)	The soil-water content after the force of gravity has drained or removed all the water. It can usually 1 to 3 days after rainfall.
Permanent wilting point (PWP)	The soil-water content of which healthy plants can be no longer extract water from the soil at a rate fast enough to recover from wilting. PWP is considered the lower limit of plant available water.
Plant Available Water (PAW)	The amount of water held in the soil that is available to plants; the difference between field capacity and the permanent wilting point.
Depletion Volume	The amount of plant – available water removed from the soil by plants and evaporation from the soil surface.
Allowable Depletion Volume	The amount of plant – available water that can be removed from the soil without seriously affecting plant growth and development.
Effective root depth	The upper portion of the root zone where plants get most of the water. Effective root depth is estimated as one-half the maximum rooting depth.

The water balance method lacks high accuracy, but it proved to be reliable and affordable in many conditions (Jones, 2004). The main difficulty is estimating ET.

2. Plant basis or plant indices:

As the plant is the user of water, it can be taken as a guide for scheduling irrigation. The deficit of water will be reflected by plants itself such as dropping, curling or rolling of leaves and change in foliage colour as indication for irrigation scheduling. However, these symptoms indicate the need for water. They do not permit quantitative estimation of moisture deficit.

Growth indicators such as cell elongation rates, plant water content and leaf water potential, plant temperature leaf diffusion resistance etc. are also used for deciding when to irrigate. Some indicator plants are also a basis for scheduling irrigation e.g. sunflower plant which is used for estimation of PWP of soil is used in Hawaii as an indicator plant for irrigation sugar cane.

Changes in stomatal conductance are particularly sensitive to developing water deficits in many plants and therefore potentially provide a good indicator of irrigation need in many species. It is in this area that most effort has been concentrated on the development of practical, *plant-based irrigation scheduling* approaches. Although stomatal conductance can be measured accurately using widely available diffusion porometers, measurements are labour-intensive and unsuitable for automation. The recognition leaf temperature tends to increase as plants are droughted and stomata close led to a major effort in the 1970s and

1980s to develop thermal sensing methods, based on the newly developed infrared thermometers, for the detection of plant stress.

A. Crop Water Stress Index (CWSI) based

An early method of accounting for the rapid short-term variation in leaf temperature as radiation and wind speed vary in the field was to refer leaf temperatures to air temperature and to integrate these differences (e.g. the Stress Degree Day measure of Jackson *et al.*, 1977); significant elevation of canopy temperature above air temperature was indicative of stomatal closure and water deficit stress. The method was transformed into a more practical approach following the introduction of the crop water stress index (CWSI) by Idso and colleagues (Idso *et al.*, 1981; Jackson *et al.*, 1981), where *CWSI* was obtained from the canopy temperature (Tcanopy) according to

$$CWSI=(T_{canopy}-T_{nws})/(T_{dry}-T_{nws}) \qquad (1)$$

Where Tnws is a so-called non-water-stressed baseline temperature for the crop in question at the same atmospheric vapour pressure deficit, and Tdry is an independently derived temperature of a non-transpiring reference crop (Fig.). In this approach all temperatures are expressed as differences from air temperature so that standard relationships for Tdry and Tnws can be used. Although this approach was found to be useful in the clear arid climate of Arizona where the method was developed, it has proved to be less useful in more humid or cloudy climates where the signal-to-noise ratio is somewhat smaller. In spite of its deficiencies, there has been widespread use of infrared thermometry as a tool in irrigation scheduling in many, especially arid, situations, especially with the development of 'trapezoidal' methods involving the combination of temperature data with a visible/near infrared vegetation index.

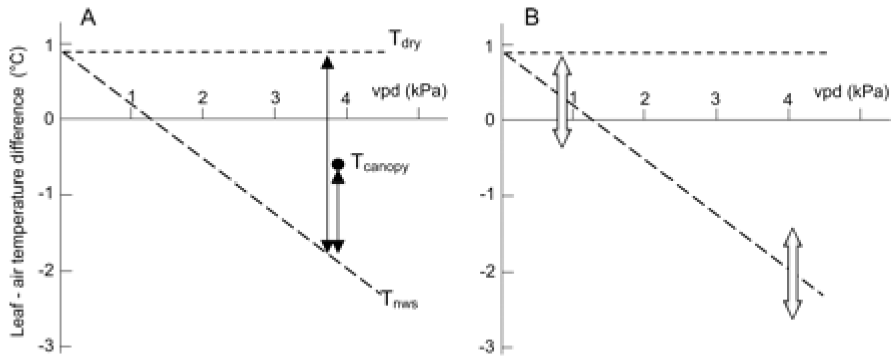

Fig. (A) Illustration of the calculation of Idso's Crop Water Stress Index: $CWSI=(T_{canopy}-T_{nws})/(T_{dry}-T_{nws})$, showing the dependence of T_{nws} (– – –) and T_{dry} (- - -) on air vapour pressure deficit (vpd, kPa). (B) Illustration of the effect of a given experimental 'noise' (for example resulting from measurement errors and variations in irradiance), indicated by the double-headed arrow, showing that the signal-to-noise ratio decreases markedly as the vpd decreases from levels found in hot and arid/semi-arid climates to values typical in humid or maritime climates.

In order to improve the precision of the approach in more humid or low-radiation environments, Jones (1999) introduced the approach of using physical dry and wet reference surfaces to replace the notional T_{dry} and T_{nws} required for above equation. A number of recent papers have shown that this approach can give reliable and sensitive indications of stomatal closure (Leinonen and Jones, 2004) and hence has the potential to be used for irrigation scheduling. The most important recent advances in the application of thermal sensing for plant 'stress' detection and irrigation scheduling, however, have been provided by the introduction of thermal imagery (Jones *et al.*, 2002), although their expense has meant that such systems have yet to be widely used.

B. Plant stress index (PSI) based

An index which will be based on the variable base point or say reference point instead of baseline needs to be developed through an alternative approach. In this regards, a new water stress index called plant stress index (PSI) is introduced. PSI is the ratio of canopy temperature difference from maximum canopy temperature to maximum and minimum canopy temperature (Pramanik *et al*. 2016). PSI can be defined as

$$PSI = \frac{(T_c - T_{cmin})}{T_{cmax} - T_{cmin}}$$

where, T_{cmin}, T_{cmax} and T_c are the minimum, maximum and observed canopy temperature respectively.

The value of PSI ranged between 0-1. Zero and one indicates non-stress and maximum stress condition of crop, respectively. The calculation of PSI needs reference canopy temperature (T_{cmax} and T_{cmin}) and observed canopy temperature in noon period (12.00 to 2.00 PM). The average value of PSI during the noon period represents the stress for that day. Two plots one under full irrigation and one under no irrigation are required to measure T_{cmin} and T_{cmax}. As the reference crop and observed crop are grown in the same environmental condition, the changes in canopy temperatures will be due to the soil moisture variation only. The variation of canopy architecture, plant height and other growth parameters can also be taken into consideration with growing stage. The index can also be used in humid and sub-humid conditions.

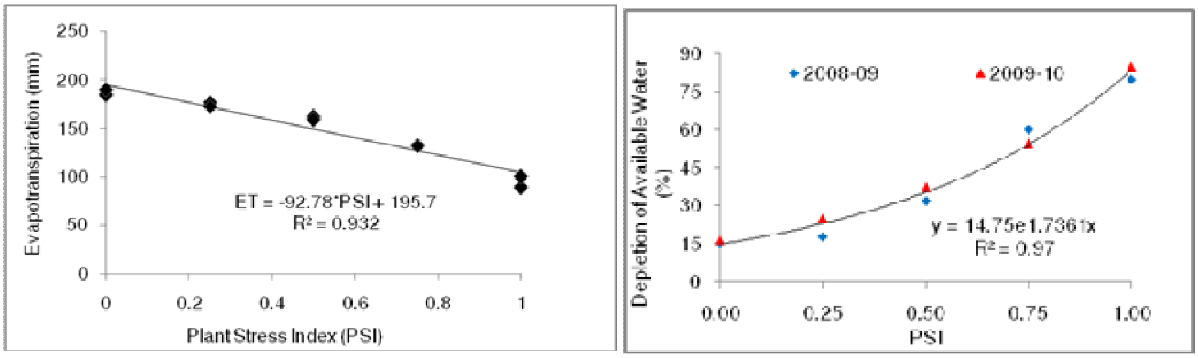

Fig. Relationship between PSI and actual evapo-transpiration and depletion of available water

3. Climatological approach:

Evapotranspiration mainly depends up on climate. The amount of water lost by evapotranspiration is estimated from Climatological data and when ET reaches a particular level, irrigation is scheduled. The amount of irrigation given is either equal to ET or fraction of ET. Different methods in Climatological approach are IW/CPE ratio method and pan evaporimeter method.

In IW/CPE approach, a known amount of irrigation water is applied when cumulative pan evaporation (CPE) reaches a predetermined level. The amount of water given at each irrigation ranges from 4 to 6 cm. The most common being 5 cm irrigation. Scheduling irrigation at an IW/CPE ratio of 1.0 with 5 cm. Generally, irrigation is given at 0.75 to 0.8 ratios with 5 cm of irrigation water.

Problem: Calculate cumulative evaporation required irrigation at 0.5 0.6 0.75 0.8 with 5 cm of irrigation water.

Solution:

Cumulative pan evaporation at IW/CPE ratio of 0.5=IW/CPE=0.5

$$= \frac{5}{CPE} = 0.5, \quad CPE \times 0.5 = 5 \qquad CPE = \frac{5}{0.5} = \frac{50}{5} \; 10cm$$

Irrigation of 5 cm is given when CPE is 10 cm

CPE at 0.6 ratio = 5/0.6 = 8.33cm

CPE at 0.75 ratio = 5/0.75 = 6.66cm

CPE at 0.8 ratio = 5/0.8 = 6.25cm

In IW/CPE ratio approach, irrigation can also be scheduled at fixed level of CPE by varying amount of irrigation water.

Problem: Calculate the amount of water for each irrigation for scheduling irrigation at 0.5 and 0.8 IW/CPE with 10cm of CPE.

Solution:

Amount of water to be given at IW/CPE ratio of 0.5=IW/10=0.5 IW=0.5 X 10= 5cm

Amount of water to be given at IW/CPE ratio of 0.8 =IW/10=0.8, IW=10 X 0.8=8cm

Estimating Evapo-Transpiration from Evaporation Data:

It is been observed that a close relationship exists between the rate of CU by crops and the rate of evaporation from a well-located evaporation pan. The standard United States weather bureaus class A pan evaporimeter or the sunken screen pan evaporimeter may be used for measurement of consumption use.

U.S class A Evopometer:

It is most widely used evaporation pan. It is made of 20 gauge galvanized iron sheet 120 cm. in diameter by 25cm. in depth and is painted white and exposed on a wooden frame in order that air may circulate beneath the pan. It is filled with water to depth of about 20 cm. The water surface level is measured daily by means of hook gauge in a still well. Difference between two daily readings indicates the evaporation if there is no rainfall. When there is rainfall, record it separately with a rain gauge. Add that value to the initial water level in the still well. Difference between this reading and subsequent reading of the water would indicate evaporation. Water is added each day to bring the level to fixed point in the still well. A measuring cylinder can also be used for this purpose.

Sunken Screen Evaporimeter:

The sunken screen pan evaporimeter developed by Sharma and Dastane (1968) at the I.A.R.I., New Delhi provides a simple device to make reasonable estimate of CU. The ratio between evapo-transpiration and evaporation from U.S.W. class A pan (ET/E) is about 0.5 to

1.3 after establishment of the crop. The same ratio is the sunken screen pan evaporimeter was observed i.e. 0.95 to 1.05.

It consists of three parts, namely an evaporation pan, a stilling well and a connecting tube. The evaporation is 60 cm. in depth, is made of 20ngague galvanized iron sheet, and is painted white. it is fitted with a screen of 1/24 or 6/20 mesh, which is held tight over the pan by bending it at the rim and pressing hard. The stilling well is 15 cm. in diameter 45 cm. in depth and is fitted with a screen cover of the same mesh as that of the evaporation pan. It has a pointer to its side of the wall and bent upward in the center at right angle. The evaporimeter is installed by digging a pit of suitable size placing the pen and back filling the earth with due to compaction the top edge of the protrudes (sickout) 10 cm. over the soil surface. This is necessary to avoid run-off from the surrounding area entering the pan. The water level is maintained at same height as the soil level outside. Thus, the tip of the pointer free water surface in the pan and the pan and soil surface are at the same level.

The water level in the pan is brought in level with the pointed tip and pan is set at work. Observations of falling water level are recorded at suitable intervals say 24 hours. This is done by adding water with a measuring cylinder and recording the quantity of water added to bring the water level back to the pointer tip. The volume of water (ml) added is converted in to depth (mm) by dividing the area of pan plus that of stealing well.

The evaporimeter is installed in duplicate to enable leakage detection. The minimum distance between two evaporimeter is 3 meter. The pan is cleaned occasionally and painted white once in a year and cheeked scrupulously for leakages. The evaporimeter is located under natural conditions in a field, which does not provide obstruction to wind. It is aligned perpendicular to the main direction of wind to avoid mutual interference.

4. Critical growth approach:

In each crop, there are some growth stages at which moisture stress leads to irrevocable yield loss. These stages are known as critical periods or moisture sensitive periods. If irrigation water is available in sufficient quantities, irrigation is scheduled whenever soil moisture is depleted to critical moisture level, Say 25 or 50 percent of available soil moisture. Under limited water supply conditions, irrigation is scheduled at moisture sensitive stages and irrigation is skipped at non-sensitive stages. In cereals, panicle initiation, flowering, and pod development are the most important moisture sensitive stages.

Table 1: Moisture sensitive stages of important crops

Sr. No.	Crop	Important Moisture Sensitive Stages
1	Rice	Panicle Initiation, Flowering
2	Wheat	Crown Root Initiation, Jointing, Milking
3	Sorghum	Seedling, Flowering
4	Maize	Silking. Tasseling
5	Bajara	Flowering, Panicle Initiation
6	Nachani	Panicle Initiation, Flowering
7	Ground Nut	Rapid Flowering, Pegging, Early Pod Formation
8	Red Gram	Flowering & Pod Formation
9	Green Gram	Flowering & Pod Formation

10	Black Gram	Flowering & Pod Formation
11	Sugarcane	Formative Stage
12	Sesamum	Blooming stage to Maturity
13	Sunflower	Two weeks before & after flowering
14	Safflower	From rosette to flowering
15	Soybean	Blooming & seed formation
16	Cotton	Flowering & Ball Formation
17	Tobacco	Transplanting to Full Bloom
18	Chilies	Flowering
19	Potato	Tuber Initiation to Tuber Maturity
20	Onion	Bulb Formation to Maturity
21	Tomato	From the Commencement of Fruit Set

5. Plant water status itself:

This is the latest approach for scheduling of irrigation. Plant is a good indicator of a soil moisture and climate factors. The water content in the plant itself is considered for scheduling irrigation. It is however, not yet common use for want of standard and low cost technique to measure the plant water status or potential.

The application of plant-based seems more practical and affordable in greenhouse soilless growing systems, where climate and crop are generally more uniform compared with open field. In these systems, the growers can make use of small-size electronic weighing lysimeters to measure, on a minute-to-minute basis, ET and the volume and EC of drainage water.

Conclusion, Future concerns and thrusts areas,

Accurate irrigation scheduling is crucial to maximize WUE and reduce nutrient leaching in intensive vegetable production systems. Different approaches may be adopted for efficient irrigation management, each having both advantages and disadvantages (Table 2). Despite the development in irrigation scheduling, in most regions worldwide (especially in less developed countries), many growers still rely on personal experience for determining crop water requirements and the timing of irrigation. Rather than to the lack of consistent methods for irrigation scheduling and off-the-shelf irrigation controllers, the main constraints to the improvement of irrigation efficiency seem related to the overall cost of these technologies and to the policies adopted for their dissemination and transfer to professional growers.

Table 2: A summary of the main classes of irrigation scheduling approaches, indicating their main advantages and disadvantages

Approach	**Advantages**	**Disadvantages**
I. Soil water measurement		
(a) Soil water potential (tensiometers, psychrometers, etc.)	Easy to apply in practice; can be quite precise; at least water content measures indicate 'how much' water to apply; many	Soil heterogeneity requires many sensors (often expensive) or extensive monitoring programme (e.g. neutron probe); selecting

(b) Soil water content (gravimetric; capacitance/TDR; neutron probe)	commercial systems available; some sensors (especially capacitance and time domain sensors) readily automated	position that is representative of the root-zone is difficult; sensors do not generally measure water status at root surface (which depends on evaporative demand)
II. Soil water balance calculations		
(Require estimate of evaporation and rainfall)	Easy to apply in principle; indicate 'how much' water to apply	Not as accurate as direct measurement; need accurate local estimates of precipitation/runoff; evapotranspiration estimates require good estimates of crop coefficients (which depend on crop development, rooting depth, etc.); errors are cumulative, so regular recalibration needed
III. Plant 'stress' sensing		
(Includes both water status measurement and plant response measurement)	Measures the plant stress response directly; integrates environmental effects; potentially very sensitive	In general, does not indicate 'how much' water to apply; calibration required to determine 'control thresholds'; still largely at research/development stage and little used yet for routine agronomy (except for thermal sensing in some situations)
(a) Tissue water status	It has often been argued that leaf water status is the most appropriate measure for many physiological processes (e.g. photosynthesis), but this argument is generally erroneous (as it ignores root–shoot signalling)	All measures are subject to homeostatic regulation (especially leaf water status), therefore not sensitive (isohydric plants); sensitive to environmental conditions which can lead to short-term fluctuations greater than treatment differences
(i) Visible wilting	Easy to detect	Not precise; yield reduction often occurs before visible symptoms; hard to automate
(ii) Pressure chamber (ψ)	Widely accepted reference technique; most useful if estimating stem water potential (SWP), using either bagged leaves or suckers	Slow and labour intensive (therefore expensive, especially for predawn measurements); unsuitable for automation
(iii) Psychrometer (ψ)	Valuable, thermodynamically based measure of water status; can be automated	Requires sophisticated equipment and high level of technical skill, yet still unreliable in the long term
(iv) Tissue water content (RWC, leaf thickness [γ- or β-ray thickness sensors], fruit or stem diameter)	Changes in tissue water content are easier to measure and automate than water potential measurements; RWC more directly related to physiological function than is total water	Instrumentation generally complex or expensive, so difficult to get adequate replication; water content measures (and diameter changes) subject to same problems as other water status measures; leaf

	potential in many cases; commercial micromorphometric sensors available	thickness sensitivity limited by lateral shrinkage
(v) Pressure probe	Can measure the pressure component of water potential which is the driving force for xylem flow and much cell function (e.g. growth)	Only suitable for experimental or laboratory systems
(b) Physiological responses	Potentially more sensitive than measures of tissue (especially leaf) water status	Often require sophisticated or complex equipment; require calibration to determine 'control thresholds'
(i) Stomatal conductance	Generally a very sensitive response, except in some anisohydric species	Large leaf-to-leaf variation requires much replication for reliable data
– Porometer	Accurate: the benchmark for research studies	Labour intensive so not suitable for commercial application; not readily automated (though some attempts have been made)
– Thermal sensing	Can be used remotely; capable of scaling up to large areas of crop (especially with imaging); imaging effectively averages many leaves; simple thermometers cheap and portable; well suited for monitoring purposes	Canopy temperature is affected by environmental conditions as well as by stomatal aperture, so needs calibration (e.g. using wet and dry reference surfaces)
– Sap-flow sensors	Sensitive	Only indirectly estimates changes in conductance, as flow is also very dependent on atmospheric conditions; requires complex instrumentation and technical expertise; needs calibration for each tree and for definition of irrigation control thresholds
(ii) Growth rate	Probably the most sensitive indicator of water deficit stress	Instrumentation delicate and generally expensive

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e-BEAM: AN IRRADIATION TECHNOLOGY FOR MICROBIAL INACTIVATION OF FOOD

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Abstract

The e-Beam irradiation technology is a safe, residue free technique for microbial decontamination of food. It also helps in increasing the shelf life of the food. The uniqueness of this is, it can also be applied to packaged foods which in turn help in mid marketing decontamination when the food is suspected to be spoiling.

Keywords: Food safety, Irradiation, e-Beam, Radura.

Introduction

The global population has reached to 7 billion and is expected to increase to over 9 billion by 2024, increases the demand of food. Lots of research has been done to increase the productivity of grains, fruits and vegetables. Productivity has almost reached its peak, leaving behind minimal scope for further growth in production. All we can do is reduce food spoilage and loss of food occurring between the farm and the consumer. Major reasons behind the wastage of food is improper post-harvest handling and processing, lack of refrigerated transportations and planning, inadequate storage structure, poor distribution. Food is wasted due to improper post-harvest handling and processing, lack of planning, refrigerated transportation, poor distribution and improper storage practices. In developing countries, almost 75 per cent of the food that is produced is lost during post harvest processing (Godfray *et al*., 2010). Thus, there is significant need for development of technology solutions regarding food processing and transportation. To meet these demands, food industry is investing in non-thermal processing research and development (R&D) for pathogen elimination and shelf-life extension. One such technology, food irradiation, is applicable to a wide variety of foods.

Food irradiation

In 1905, a British patent was awarded for invention in "improving the condition of food materials and increasing their keeping quality." Food irradiation technology is over 100 years old. It is one of the most efficient and extensively used techniques in food industry. It has been declared as a safe and efficient measure of food preservation by different international governing bodies *viz.* the World Health Organization (WHO), the United States Food and Drug Administration (FDA), Food and Agriculture Organization (FAO), the International Atomic Energy Agency (IAEA), the United States Department of Agriculture (USDA) and Codex Alimentarius etc. At present, this technology has been approved in over 50 countries and is being commercially available for foods like fresh and frozen meats, fresh produce, spices and food ingredients.

It is, however, one of the most ignored and pilloried in food industry because of the false accusations like ‘irradiation makes food radioactive and causes deadly diseases like cancer and this technology being used to “cover up dirty practices.” Despite all the negative publicity, this technology is used extensively for decontamination of spices and seasoning etc.

The principle behind irradiation technology is to utilize the ionising radiation like X-Rays, γ- Rays, electron beam etc., to achieve the desired end result of microbial inactivation. These rays generate high ionizing energy to inactivate/kill the pathogen, without harming the constituent of food and altering its properties, when applied at a particular dose. Although the working principle of all the irradiation technologies is same, but they may differ in the way they are generated, depth of penetration and recommended dose.

Fig. 1: The Radura- the international symbol showing that food has been irradiated, with alternative “Statements of Irradiation.”

The symbol of ‘Radura’ symbol (Fig.1) on the package of the processed product identifies that the food has been irradiated. It is a must for the food processor to share the importance of food irradiation and its benefits with the consumer. Table 1 shows the dose rates of gamma, X-ray, and e-Beam irradiation at different beam energy levels, as measured at the National Centre for Electron Beam Research at Texas A&M University.

Table 1: The beam energy and corresponding dose rate of e-Beam, gamma, and X-ray radiation.

Source	**Energy, MeV**	**Dose Rate, Gy/s**
Electron Beam	10	~3,000
Gamma	1.59 (from lanthanum-140)	~0.06–0.12
X-Ray	5	~100
	0.1	~0.01

This technology not to be used as “clean up or product reclamation” technology for sub-standards products harbouring spoilage organisms or microbial pathogens. It is concluded that at proper dose, the process contributes to achieving safe and wholesome foods. Irradiation technology will yield the highest returns of investment for high quality products if it is used to provide finishing touch. Among all the irradiation technologies, e-Beam is one of the cheapest, safest and radioactive free.

Fig. 2: Irradiated foods with Radura symbol

e- Beam Technology

Electron-beam (e-Beam) irradiation uses beta (β) radiation of high energy to treat an object for a variety of purposes like sterilization. It is in particular, might be suitable to be applied in food products with reduced thickness, such as aromatic and medicinal plants. e-Beam irradiation, also known as “electronic pasteurization” or “cold pasteurization”; does not alter the physical and chemical properties of the food products it is applied to. Results of electron beam irradiation mirror the food safety intervention results that are achieved by milk pasteurization, water chlorination, and the protection of the public’s health through immunization against life-threatening or deadly diseases.

e-Beam is ‘switch-on/switch-off’ technology i.e. the generation of the radiation can be started or stopped at any time (in contrast to γ- rays , whose production cannot be stopped once the process of generation started) which saves lot of energy, makes it easy for transportation and economically efficient ultimately saving processing cost.

The physics of electron beam irradiation

The basic components of a typical electron-beam processing unit are

1. An electron gun consisting of a cathode, grid and anode- used to generate and accelerate the primary beam

2. A magnetic optical focusing and deflection system- used for controlling the way in which the electron beam impinges on the material being processed (the "work piece")

The electrons are generated from a cathode tube under vacuum using 220-240 V and 50 Hz 3 phase electrical system. The electrons are then fired or pulsed from an electron gun (e-Gun) at an elevated temperature through the exit hole in the ground plane anode plate with very high energy value, creating a beam of electrons. The beam of pulsed electrons is carried across a radio frequency (RF) wave length in the linear accelerator (LINAC), which has positively and negatively charged cavities that increase the speed of the beam as it travels across the RF waveform through the accelerator. This increases the speed of electron to 99.99 per cent the speed of light at energies not to exceed 10 Million electron Volts (MeV), which are able to break molecular or atomic bonds releasing free electrons and ions that react with additional particles, charged molecules or atoms, to release secondary ions.

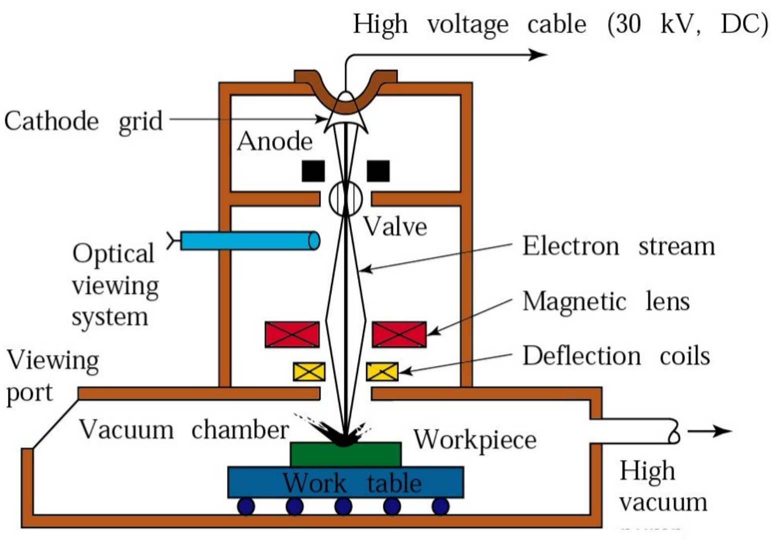

Fig. 3: Electron Beam Irradiation System Set-up

e-Beam in Food Industry

In food industry, when e-Beam is applied at a specific dose (0.1-10 kGy), it damages the DNA and RNA chains of the food borne pathogens, which has a lethal or quarantine effect on them. The ability of e-Beam to pass through the packaged food and its residue free nature makes it a great intervention towards food safety.

The FDA regulates the use of this technology for sterilizing medical devices, pharmaceuticals and food processing in general. The FDA has established maximum doses that can be applied to different types of foods, spices and seasonings. The USDA Food Safety and Inspection Service (FSIS) oversees the application of this technology to fresh and frozen meat and poultry products and the USDA Animal and Plant Health Inspection Service (APHIS) oversees its use for phytosanitary treatment of fresh fruits and vegetables.

Table 2: The FDA has set maximum allowable dosages for food irradiation applications

Food or Food Ingredient	Application	Maximum Allowable Dose, (kGy)
White potatoes	Sprouting inhibition	0.15
Fresh, non-heated processed pork	Pathogen control	0.3–1.0
Wheat flour	Mould control	0.5
Fresh produce	Insect disinfestations	1.0
Fresh produce	Growth and maturation inhibition	1.0
Frozen or fresh uncooked poultry products	Pathogen control	3.0
Fresh shell eggs	Pathogen control	3.0
Fresh iceberg fresh spinach and lettuce	Pathogen control	4.0
Refrigerated, uncooked meat products (sheep, cattle, swine, and goat)	Pathogen control	4.5
Frozen and fresh molluscan shellfish	Pathogen control	5.5
Frozen, uncooked meat products (sheep, cattle, swine, and goat)	Pathogen control	7.0

Food processing applications of e-Beam technology can be broadly divided into low-energy (<1 MeV), medium-energy (1–8 MeV) and high-energy (8–10 MeV) applications. Currently, low-energy applications include the inline sterilization of packaging materials and the inline disinfestations/sterilization of seed surfaces. Medium-energy applications include phyto-sanitary treatment of packaged fruits and vegetables. High-energy applications include pasteurization of packaged meats, spices, sea-food and food ingredients.

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Black Rice: THE NUTRACEUTICAL GRAIN

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Introduction

Black rice has a rich cultural history; called "Forbidden" or "Emperor's" rice, it was reserved for the Emperor in ancient China and used as a tribute food. In the time since, it remained popular in certain regions of China and recently has become prized worldwide for its high levels of antioxidants. Despite its long history, the origins of black rice have not been clear. Black rice cultivars are found in locations scattered throughout Asia. However, most cultivated rice (*Oryza sativa*) produces white grains, and the wild relative *Oryza rufipogon* has red grains.

Black rice is a type of the rice species *Oryza sativa* L. which is glutinous, packed with high level of nutrients and mainly cultivated in Asia. The pericarp (outer part) of kernel of this rice colour is black due to a pigment known as anthocyanin, an antioxidant. It is also known as purple rice, forbidden rice, heaven rice, imperial rice, king's rice and prized rice. Many people assumed that this rice as a panacea of many culinary diseases because of its high nutritive value and curative effect. The rice is supposed to enhance the longevity of life; hence also known as long life rice. This rice includes several varieties with a long history of cultivation in Southeast Asian countries such as China, India and Thailand (Kushwaha, 2016).

The trait of black grain originated from ectopic expression of the Kala4 promoted basic helix-loop-helix (bHLH) gene due to rearrangement in the promoter region. Chalcone synthase and dihydroflavonol-4-reductase activated by Rc and Kala4 genes which accelerated to upstream flavonol biosynthesis genes and downstream genes, such as leucoanthocyanidin reductase and leucoanthocyanidin dioxygenase, to produce the respective specific pigments (Oikawa *et al.*, 2015). Genomic analysis of black rice varieties as well as red and white grained landraces indicated that black rice has been arose in tropical japonica and its subsequent spread to the *indica*, subspecies can be attributed to the causal alleles of Kala4. The genomic fragments of tropical japonica has relatively small size that originated in some *indica* varieties indicates that refined introgression must have occurred by natural crossbreeding in the course of evolution of the black trait in rice (Oikawa *et al.*, 2015).

Geographical distribution

It is found that approximately 200 types of black rice varieties have been reported in the world. Among country, China produces 62 % of global production and has developed more than 54 modern black rice varieties with high yield potential and multiple resistances. Thereafter, Sri Lanka, Indonesia, India, Philippines and other countries found placed. Thailand occupies ninth position in its cultivation (Kushwaha, 2016).

Black rice is indigenous to north-east India and is extensively grown in Odisha, West Bengal and Jharkhand. It is commonly eaten in Manipur because of its medicinal value.

Called *chak-hao*, meaning rice (*chak*) which is delicious (*ahaoba*), black rice is eaten during traditional feasts. *Chak-hao kheer* is a popular pudding in these regions and the water in which it is boiled, is used to wash their hair with belief that it makes hair strong (Dahiya, 2018).


Fig. 1. Black rice

(***Source:*** http://thirdlifeindulan.com.)

Table 1: Nutrition value of black rice (Values per 100 g)

Nutrient	**Amount**	**Nutrient**	**Amount**
Alanine	0.437 g	Lysine	0.286 g
Arginine	0.569 g	Magnesium, Mg	143 mg
Ash	1.27 g	Manganese, Mn	3.743 mg
Aspartic acid	0.702 g	Methionine	0.169 g
Calcium, Ca	33 mg	Niacin	4.308 mg
Carbohydrate, by difference	76.17 g	Pantothenic acid	1.493 mg
Copper, Cu	0.277 mg	Phenylalanine	0.387 g
Cystine	0.091 g	Phosphorus, P	264 mg
Energy	1515 kj	Potassium, K	268 mg
Energy	362 kcal	Proline	0.352 g
Total monounsaturated	0.971 g	Protein	7.50 g
Total polyunsaturated	0.959 g	Riboflavin	0.043 mg
Fatty acids, total saturated	0.536 g	Serine	0.388 g
Fiber, total dietary	3.4 g	Sodium, Na	4 mg
Folate, DFE	20 mcg_DFE	Thiamin	0.413 mg
Folate, food	20 mcg	Threonine	0.275 g
Folate, total	20 mcg	Total lipid (fat)	2.68 g
Glutamic acid	1.528 g	Tryptophan	0.096 g
Glycine	0.369 g	Tyrosine	0.281 g
Histidine	0.190 g	Valine	0.440 g
Iron, Fe	1.80 mg	Vitamin B-6	0.509 mg
Isoleucine	0.318 g	Water	12.37 g
Leucine	0.620 g	Zinc, Zn	2.02 mg
			Source: http://www.blackrice.com/nutrition/

Recipes from Black rice

1. Baked orange cauliflower and forbidden rice 2. Miso forbidden rice bowls 3. Black rice ramen with garlic matcha chickpeas 4. Black rice pudding with coconut and mango 5. Forbidden cold ramen 6. Black fried rice with snap peas and scallions 7. Black rice tabbouleh with chickpeas feta and pistachios 8. Soy ginger shrimp with forbidden rice	9. Black rice noodle bowl with roasted squash and creamy miso dressing 10. Thai chicken forbidden rice soup 11. Black rice and arborio risotto with artichokes 12. Black rice and spinach salad 13. Senposai, daikon and chili garlic chicken wraps 14. Mango sticky rice lassi parfait 15. Porcini mushroom, greens and forbidden rice gratin 16. Black rice, beet and kale salad with cider flax dressing
	Source: https://www.brit.co › Food › Recipes

Medicinal Properties

This rice has quickly become known as a ‘super food’. ‘Super foods’ are certain types of foods that offer many consequential health benefits aside from their inherent caloric and nutritional value.

1. It contains more Vitamins B and E, niacin, calcium, magnesium, iron and zinc as compared to white rice. It is rich in fiber and the grains have a nutty taste. The anthocyanins not only act as antioxidants, they also activate detoxifying enzymes.
2. It is rich in vitamin E (which strengthens the immune system and promotes healthy skin and eyes), iron (which helps make red blood cells), manganese (which aids the nervous and reproductive systems) and other minerals.
3. This rice naturally consists of no gluten (protein present in all wheat, rye and barley products). Consuming black rice might help remove digestive problems related to gluten for most of the people (Anonymous, 2018).
4. The rice arrests proliferation of cancerous cells, by inducing death of cancerous cells (apoptosis). American Health Association, American Cancer Society and the Dietary Guidelines for Americans (2005) recommended an increase in the consumption of black rice to prevent heart disease and certain kinds of cancers (USA Rice Federation, 2008).
5. The health benefits of black glutinous rice have been reported by several investigators and reported that anthocyanin supplementation in humans improves LDL and HDL levels (Qin *et al.* 2009) and can delay cancer development in rodent’s models of carcinogenesis.
6. In fact, it prevents invasion of cancer cells and induces differentiation – the greater the differentiation in cancerous cells, the less likely they are to spread. The research, in particular, showed that anthocyanins from black rice specifically arrests growth of breast cancer cells.

7. It has anti-inflammatory properties and anti-angiogenesic effects (inhibition of the formation of new blood vessels which encourages tumour growth).

The way forward to plan for India

The Government of India should take step for the popularization of black rice cultivation. However, few institutions are working for creation of awareness among farmer to adopt black rice cultivation and enhance income. Black rice must be include in area of normal rice cultivation, so that its benefit cannot be ignored and harvest more nutrition from black rice. A special market that attracts the grower can be established primarily for export purposes. The infrastructure, market support and financial incentives should provide by government to the farmer so that cultivation of black rice can be promoted.

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CULTIVATING DRAGON FRUIT FOR FARMER'S PROSPERITY IN BUNDELKHAND

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Abstract

There is considerable potential for the expansion of dragon fruit in Bundelkhand region of India. This region is unique in many aspects being the central part of the country. Bundelkhand is spread over Southern Uttar Pradesh and Northern Madhya Pradesh characterized by low and erratic rainfall and harsh climatic conditions. Dragon fruit is suitable for growing in regions that have spells of dry weather with supplementary irrigation. Except for the high establishment cost due to the trellis for plant support, the other agronomic practices are easy and less expensive, hence it has low maintenance cost. In addition once planted, it will grow for 20 years with a density of around 800 plants / ha. The yield is high with the selling price of Rs 200-250 per kg in India and being a regular bearing and precocious early yielding it brings early income to the growers. This crop could be an asset to the smallholders as well as the establishment of large scale plantations. Therefore, promotion of dragon fruit production in the dry, arid and semi arid areas like Bundelkhand will give immense advantages of its economic and nutritional benefits to the farmers.

Introduction

Dragon fruit (*Hylocereus undatus*) is a climbing vine cacti and is tropical in nature. Its flower bloom only at night, hence the plant is sometimes also called the moonflower or Lady of the Night. They are bell-shaped and produce a sweet fragrance when in bloom. Its fruit is the most beautiful among all in the Cactaceae family with a bright red skin studded with green scales and white or red flesh with tiny black seeds which resembles those of a kiwi and are edible. Apart from being refreshing and tasty, it is a rich source of vitamin C, calcium and phosphorus which helps in development of strong bones, teeth and skin. The fruit also posses medicinal properties and is considered as "health fruit". The red fleshed varieties are rich in antioxidants. It is known to prevent colon cancer, diabetes, reduce cholesterol, high blood pressure, control high sugar level, prevent cancer and promote dental health. The detailed composition of the fruit is as presented in Table 1.

Table 1. Average nutritional composition of dragon fruit

Composition	Per 100 gram of fruit pulp	Composition	Per 100 gram of fruit pulp
Water (g)	82.50-83.00	Phosphorus (mg)	30.20-36.10
Protein (g)	0.16-0.23	Iron (mg)	0.55-0.65
Fat (g)	0.21-0.61	Vitamin C (mg)	8.00-9.00
Crude fiber (g)	0.70- 0.90	Thiamin (mg)	0.28-0.30
Carotene (mg)	0.005-0.012	Riboflavin (mg)	0.04-0.05
Calcium (mg)	6.30-8.80	Niacin (mg)	1.29-1.30

Plate 1. Dragon fruit Plate 2. The cut pieces of red and white dragon fruit

Climate and Soil

The plant can tolerate poor soil conditions and temperature variations. Tropical climate is good for dragon fruit cultivation. It requires an optimum temperature range of 20 - 30° C and about 1142 – 2500 mm annual rainfall with alternate dry and wet climatic condition. Excessive rainfall may cause flower to drop and fruit rot. It needs good sunlight, but not suitable for long period, so shading should be provided when there is long period exposure to sunlight. The fruit can be grown on a wide range of soil provided that there is enough of drainage, as the plant cannot tolerate water logging. Sandy loam soils with good amount of organic matter provide good condition for plant growth.

Propagation

Dragon fruit can be propagated by two methods *viz.*, seed and cutting. The seeds are collected from selected fruits of mother plant, washed and sown in potting mixture from which they germinate within 3-4 days. The seedlings can be potted in 4-5 weeks after germination. They are ready for planting in field within 9 – 10 months. The plants propagated through seeds are not true to type and take time to come to bearing age. So, commercially cutting is preferred means of propagation which is easiest and cheapest method. Cuttings should be collected after fruiting of mother plants. Cuttings should be 15 to 60 cm long, the longer the cutting, the more will be its stored food material which will lead to more success. The cuttings should be planted in a potting mixture containing dry cow dung, top soil and sand in the ratio of 1:1:2 and should be placed in a shady place away from direct exposure to sunlight.

Planting

The shifting of the plants to field should be done either in morning or late afternoon. The plant requires full sunlight and therefore it should be planted in an open field. The planting distance can be 3x3, 3x4, 3x4.9 or 3.7x3.7 m^2 accomodating 1100, 833, 680 and 730 plants/ ha. The pit should be about 30 cm deep and 20 cm wide. The supporting post should be fixed at the center of the pit well in advance by embedding it on concrete to make it firm to enable the vine to climb on it. The dragon fruit plants are placed near the post to enable them to climb on it. The number of plants to each post may vary from 1-4. The best planting time is rainy season during late afternoon or morning.

Trellising

As the dragon fruit is a climbing cacti, the vine should be trained to climb a concrete or wooden post, fence etc. for support. There should be a post for each vine and as the life of the vine is 20 years, so a durability of post is of prime importance. The post has to be very strong as a 3-4 year old vine can weigh about 100 kg, hence only concrete post will be able to hold the weight. The post should have 100-200 mm diameter and 2 m high and should be buried 40 cm in the ground. A used rubber tyre, cut cross wise and placed on the top of the post can be used to train the vine.

Plate 3. Trellising of dragon fruit

Plate 4. Fruit development on plant

Irrigation

Dragon fruit though a member of family Cactaceae, requires plenty of water for their growth because they have originated from tropical rainforests and have a root system distributed in top 15-30 cm of soil, hence irrigation is required to ensure the needed soil moisture content particularly during dry spells. The rainfall requirement is 1142-2500 mm per year. The crop should be to subjected to dry period during pre bloom period to ensure good flowering. Then the soil should have enough moisture from flowering to fruit development. Micro irrigation methods are best and mulching prevents the evaporation losses.

Fertilizer application

Dragon fruit requires judicious application of fertilizers for higher yields. The recommendation of fertilizers rate vary widely. The crop has to be fertilized frequently in the early phase of growth. In Hawai, a 16-16-16 NPK mixture is applied at 4-6 monthly intervals at 180-230 g/plant. Calcium and micronutrients are applied to enhance fruit quality. The plant of dragon fruit requires 10 to 15 kg of organic fertilizers for good vegetative growth. Each plant requires 70 g urea, 90 g SSP and 40 g MOP per plant in vegetative phase. High amount of potash and low amount of nitrogen during bearing stage should be applied to obtain high yield.

Training

The plants grow very fast and reach the trellis in very short time. As the vines grow, they may fall to the ground and severe damage may occur. Tying vines loosely to the trellis can prevent this. The lateral vines should be pruned when the vines grow towards the trellis and only outer leader vines should be allowed to grow. The vines grow very rapidly and form thick dense mass of vines on the top of trellis. After harvest, there should be about 50 main branches with one or two secondary branches on main branches. The tertiary and quarterly branches should be removed. The excess stems and those that are dead and diseased should be removed. The pruning cuts should be treated with fungicides. The cut portion of the vines should be removed from the field to prevent contamination and the healthy cuttings can be used as a propagule.

Pest and disease

Dragon fruit is comparatively free of pests. The common pests reported from different countries are ants, scale insect, mealy bugs, beetles, slugs, snails, borers, caterpillars, termites, nematodes, fruit flies, bats, rats and birds. These pests should be monitored regularly and controlled when observed. Among diseases, a soft watery stem rot caused by *Xanthomonas compestris* common due to over watering or in wet weather has been reported. Brown spots caused by *Anthracnose* has also been reported. *Anthracnose* also attacks the fruits. *Fusarium oxysporum* attacks the vines. The practice of wider spacing is suggested to improve air circulation and light penetration which in turn could reduce disease problem.

Yield

Dragon fruit bears within six to nine months and yield is obtained from second year onwards. The average yield is about 12,000 kg/ha at the end of third year. The proper management of the vines and fruit thinning improves size of the fruits and yield. The average fruit weight is about 350 g. The flowers and fruits can be thinned to improve and maintain fruit size and quality.

Harvesting

The ripening time is usually from June to December. As the fruit is non climacteric, it should be picked at maximum sugar level and acidity. At peak ripeness, the fruit becomes pink red, although the scales remain green. Peak ripening reaches 40 – 50 days after flowering. The fruits should be selectively harvested as they ripen at different times. The harvesting is done twice a week. The harvesting should be done carefully using knives without damaging the fruits. The fruits should be kept in a cool shady place before transferring them for storing.

Storage

The fruit can be stored at 7 – 10 °C and 90-98 % relative humidity for 45 days. If the fruit is moved in and out of cold storage, the shelf life is drastically reduced. The skin of the stored fruits become thinner and the water moves into the flesh from the skin. The products like jams, jelly, juice and wine can be made from the fruit.

Summary

Dragon fruit can be an asset to small holders as well as entrepreneurs of medium and large scale plantations. It is a fast return perennial crop with production in the second year after planting and has full production within five years. The yield is also high and regular bearing brings early income to the growers. It has an advantage that once planted, it will grow for 20 years and one hectare can accommodate about 800 plants. These fruits show excellence in less expected rainfall areas. Dragon fruit is ideal new crop for the dry areas and is salt tolerant to some extent and can be grown as an income generating crop in Bundelkhand region of Uttar Pradesh.

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PRECISION FARMING AND ITS ROLE IN AGRICULTURE

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Introduction

An information and technology based farm management system to identify, analyze and manage variability within fields by doing all practices of crop production in right place at right time and in right way for optimum profitability, sustainability and protection of the land resource. Precision agriculture is a systems approach to farming for maximizing the effectiveness of crop inputs.

Definition

Precision farming is generally define as an information and technology based farm management system to identify, analyze, manage variability within field from optimum profitability, sustainability and protection of land resources.

Need of precision agriculture

1. For assessing and managing field variability
2. For doing the right thing in the right place at the right time
3. For higher productivity
4. For increasing the effectiveness of inputs
5. For maximum use of minimum land unit

Components of precision agriculture

I. Information or data base

Soil: Soil texture, structure, physical condition, soil moisture and soil nutrients, etc.

Crop: Plant population, crop tissue nutrient status, crop stress, weed patches (weed type and intensity), insect or fungal infestation (species and intensity) and crop yield, etc.

Climate: Temperature, humidity, rainfall, solar radiation and wind velocity, etc.

II. Technology

Technologies include a vast array of tools of hardware, software and equipments.

1. Global Positioning System (GPS) service

GPS provides continuous position information in real time, while in motion. Having precise location information at any time allows soil and crop measurements to be mapped.

2. Differential Global Positioning System (DGPS)

A technique to improve GPS accuracy that uses pseudo range errors measured at a known location to improve the measurements made by other GPS receivers within the same general geographic area.

3. Geographic information systems (GIS)

Geographic information systems (GIS) are computer hardware and software that use feature attributes and location data to produce maps. An important function of an agricultural GIS is to store layers of information, such as yields, soil survey maps, remotely sensed data, crop scouting reports and soil nutrient levels.

4. Remote sensing

It is the collection of data from a distance. Data sensors can simply be hand-held devices, mounted on aircraft or satellite-based. Remotely-sensed data provide a tool for evaluating crop health. Plant stress related to moisture, nutrients, compaction, crop diseases and other plant health concerns are often easily detected in overhead images. Remote sensing can reveal in-season variability that affects crop yield, and can be timely enough to make management decisions that improve profitability for the current crop.

5. Variable Rate Applicator

In precision agriculture, Variable Rate Application (VRA) refers to the application of a material, such that the rate of application is based on the precise location or qualities of the area that the material is being applied.

III. Management

1. Information management

The adoption of precision agriculture requires the joint development of management skills and pertinent information databases. A farmer must have clear idea of objectives of precision farming and crucial information necessary to make decisions effectively.

2. Decision support system (DSS)

Combination of information and technology into a comprehensive and operational system gives farmers a decision to treat the field. For this purpose, DSS can be developed, utilizing GIS, agronomic, economic and environmental software, to help farmers manage their fields.

3. Identifying a precision agriculture service provider

It is also advisable for farmers to consider the availability of custom services when making decisions about adopting precise/site specific crop management. The most common custom services that precision agriculture service providers offer are intensive soil sampling, mapping and variable rate applications of fertilizer and lime.

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