IPM in wheat

for increased productivity and profitability

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India is the second largest producer of wheat in the world, next only to China. The yields grew dramatically due to the Green Revolution and today India is not only self-sufficient but also able to sustain global economic crisis. This achievement has been made possible basically through the introduction of high-yielding Mexican cultivars and then through improved cultural practices, and above all, effective management of diseases and other pests of wheat. In India wheat crop is attacked by many pests, of which rusts are major concern. The IPM is a new hope to sustain this high production and keep India moving ahead.

EVER increasing population and changes in food consumption patterns are the challenges of Indian agriculture today. Though, our food grains production has reached the all time record highest of 234 (million tonnes) during 2008 – 09 crop season and is self reliant, the sustainability of it is still a big conundrum. India has become the second largest producer of wheat in the world, next only to China. From a mere 6.2 mt in 1947 (at the time of independence) and 11.0 mt in 1965 (during the pre-green revolution era), the wheat production touched its peak at 80.58 mt during 2008-09 and is likely to cross this production level during 2009-10 (80.98 mt as per 3rd advanced estimates). This has been possible through high-yielding varieties, coupled with improved production and protection technologies. It is heartening to mention that wheat in India has not suffered any disease or pest epidemic during the last more than three decades, which in itself is a great national achievement.

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Keeping environmental, economic and health issues in view, the IPM or the Integrated Pest Management approach is the most desired one to manage the biotic stresses. This is an approach to sustainable pest management and a means to reduce reliance on pesticides and their associated risks. IPM strategy is well developed in various crops, but the wheat crop has come under focus only recently. The major emphasis has been on host resistance due to which, the crop has been genetically insulated against major biotic factors, especially the rusts, which has helped in revolutionizing the wheat yields over the years. However, the host resistance is not as strong for other pests/diseases as it is for rusts. Hence, other approaches are also needed for effective management of the pest system in wheat in a holistic manner.

The main components of IPM being utilized in wheat crop are: Pest survey and surveillance, biological control, host resistance, judicious usage of chemicals and the use of disease free and clean seed. Management of Karnal bunt disease has been achieved through the use of less hazardous chemical spray and integration of biological control with epidemiological approach. In case of loose smut disease, the integration of bioagent fungus with reduced dosage of chemical fungicide has been a major breakthrough.

Pest problems of wheat

Wheat environment in India is relatively free from pesticides in comparison to other crops, since bare minimum levels of pesticides are used in wheat. It is due to the reason that major stress in wheat is on host resistance, especially for rusts. Wheat (*Triticum aestivum*) suffers from various diseases and pests in India, the major ones being rusts (yellow, brown and black), Karnal bunt, powdery mildew, foliar blights, head scab, foliar aphid, root aphid and termites.

Rusts

Wheat rusts pose a constant threat to sustainable wheat production and thus global food security. The rusts of wheat attract most attention because wheat is one of the two most important food crops for mankind. India in particular has not faced any rust epidemic since last three and half decades because of proper

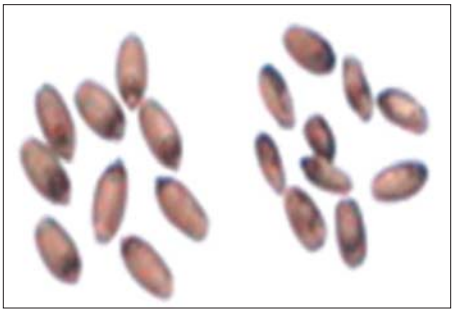
Important Diseases in Wheat

Rust

Stripe rust

Stem rust

Leaf rust



Black point and black discolouration

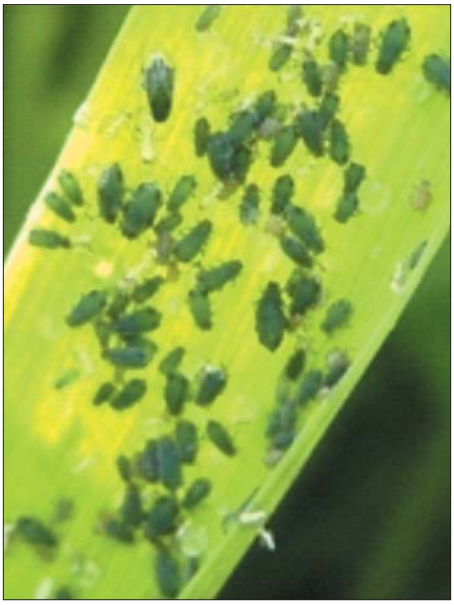
Loose smut

Foliar blight

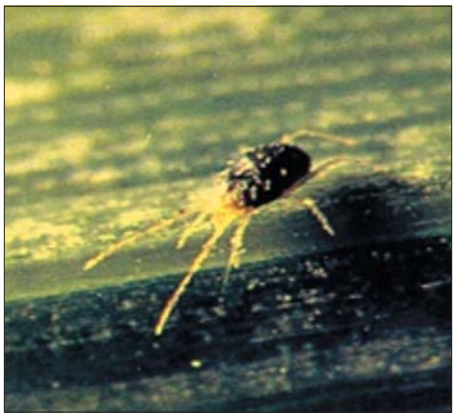
Powdery mildew

Important Diseases in Wheat

Head scab



Aphids



Brown wheat mite

Cereal cyst nematode

Flag smut

Root aphid

Seed gall nematode

Termites

Army worm

deployment of rust resistance genes in wheat breeding programmes.

Stripe rust (Yellow rust), *Puccinia striiformis*

It is distributed mainly in the North-Western hills, foothills and sub mountaineous pockets in North West Plain Zone (NWPZ), North Western Plains, Northern Hill Zone (NHZ) and Southern Hill Zone (SHZ). Stripe poses a potential threat to the main wheat belt of India, if cool and humid weather persists from December to March. Sometimes, disease inflicts yield losses in other cooler parts of the country also.

Natural enemies of wheat insect pests

Pathogen survives in the cool temperatures of hills (Himalayas and Nilgiris) and the primary infection takes place in December-January in the foot hills and sub-mountainous parts of NWPZ. Yellow rust from SHZ cannot come out of the zone due to high temperatures in the Peninsular Zone (PZ) and Central Zone (CZ).

Stem rust (Black rust), *Puccinia graminis.* f.sp. *tritici*

It is important mainly in PZ and CZ, but may occur in traces in other zones like NEPZ. It can cause severe grain losses if infection is early. The pathogen perpetuates in Nilgiri hills during off season and becomes air-borne. If PZ and CZ experience rainfall along with storm during November, then epidemics can be severe on the old or local susceptible varieties. The modern day varieties are mostly resistant to this disease. In north India, the infection occurs rarely, that too very late in the season, thus losses are negligible.

Leaf rust (Brown rust), *Puccinia triticina*

Leaf rust is among the most prevalent leaf diseases of wheat worldwide. It is distributed throughout wheat growing areas of India. Pathogen over summers in low and mid altitudes of Himalayas and Nilgiris. Primary infections develop from wind deposited uredispores in eastern Indo-Gangetic plains in middle of January where it multiplies and moves westwards by March. Temperatures of 20±5°C with free moisture (rain or dew) cause epidemics, severe infection causes up to 30% yield loss.

Karnal bunt, *Tilletia indica*

Karnal bunt (KB) of wheat caused by *Neovossia indica (Tilletia indica)* was first reported from India by Mitra in 1931 and it continued to be a minor disease till 1968. However, in 70s and 80s of 20th century, it emerged as an important disease of wheat in the country. It occurs in parts of North Western Plains Zone, especially Punjab, parts of northern Haryana, foot hills of J&K and HP, tarai area of Uttarakhand, parts of Bihar, UP and northern parts of MP. States of Maharashtra, Gujarat and Karnataka are completely free from KB. It is seed and soil-borne. Infection by this fungus impairs quality of wheat–based products and reduces seed germination. Moreso, this disease hampers export of wheat from India owing to stringent quarantine restrictions posed by several importing countries as preventive measure to avoid entry of *T. indica* into their territory. The incidence of Karnal bunt in Indian wheat has come down drastically over the years and wheat growing areas free from Karnal bunt have been demarcated for the procurement of Karnal bunt free grain lots.

Black point and black discoloration

Black point and grain discolouration or black discolouration are the major grain infecting diseases of wheat. The black point infects only the embryonic end of the grain as a small black dot, whereas in discolouration, the blackening extends beyond the grain tip to cover a major part of the grain. Black point infected grains remain bold and show no signs of shriveling while the grains infected by black discolouration get shriveled to various levels or even mummified depending upon the intensity of infection. In case of black discolouration, though *A. alternata* continues to be the dominant fungus, other fungal species like *Drechslera sorokiniana*, *Curvularia lunata*, *Epicoccum* spp. and *Fusarium* spp. were also isolated. Grain or seed infecting diseases like black discolouration and black point affect the market trade of wheat. Many a times, during trade, blackpoint or discolouration are confused with Karnal bunt disease (*Tilletia indica*) which has great quarantine implications. Hence, monitoring of these two maladies in the country carries much importance.

Loose smut, *Ustilago segatum* var. *tritici*

This is an important seed-borne disease in Northern Plains and hills and parts of Central India. It is also seen in peninsular India in traces but does not cause concern there.

Table 1. Natural enemies of insect pests of wheat ecosystem

Parasitoids/Predators	Host - Wheat
Coccinelids	Nymphs and adults of foliar aphid
Braconids	Larval parasitoid of *Helicoverapa armigera* and *Mythimna separata*
Trichogramma	Egg parasitoids of *H. armigera, Sesamia inferens* and *M. separata*
Spiders	Gundhi bug, hoppers and lepidopteran adults
Long horned grasshopper	Plant and leaf hoppers

Table 2. Economic thresholds for different insect pests of wheat

Name of Insect Pest	Threshold
Foliar aphids	10 - 12/tiller
Wireworms	One worm/3 m row
Armyworm	16 to 20/m row
Brown wheat mite	Several thousand/m row

(Modified from http://texaserc.tamu.edu)

Foliar blights, *Bipolaris sorokiniana*

The problem of leaf blight is more prominent in the north eastern region. Spot blotch caused by *Bipolaris sorokiniana* is a major biotic constraint to wheat yields in the hot and humid environments of Indo-gangetic plains of India also.

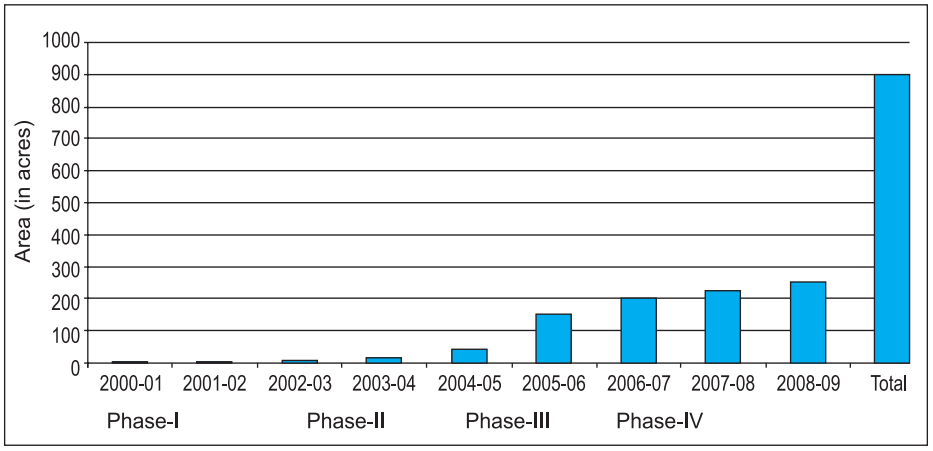
Powdery mildew, *Erysiphe graminis* f. sp. *tritici*

It is a destructive foliar disease which has recently assumed importance in north western plain zone, northern hill zone and southern hills of India. It is emerging as a new crop health problem in parts of NWPZ due to the cultivation of varieties that do not have resistance to the disease and also, the favourable microclimate created due to some of the new RCT's. The incidence of the disease has been found significantly higher on FIRBS as compared to the conventional flat bed sowing. Losses from this disease have increased in recent years in NWPZ as most of the varieties including 'PBW 343' do not possess sufficient level of resistance.

Table 3. Economic thresholds for different diseases of wheat

Growth stage	Disease	Indicator leaf	Threshold
Flag leaf extension	Leaf blight complex	F-2 leaf	25% of leaves with blotches
Flag leaf fully expanded to head emergence (Zadoks growth stage 50-59)	Powdery mildew	F-1 leaf	Average of 5 pustules/leaf
	Leaf blight complex	F-2 leaf and above	25% of leaves with blotches
Heads completely emerged through flowering (Zadoks growth stage 60-69)	Powdery mildew	F-1 leaf	Average of 5 pustules/leaf; traces on earheads or awns.
	Leaf blight complex	Flag or F-1 leaf	25% of leaves with blotches
Early milk to late milk (Zadoks growth stage 70-79)	Powdery mildew	Earhead	5-10% of earhead covered
	Leaf blight complex	Do not spray	

(Modified from: http://www.kyssmallgrains.org/productionalmanual/diseasemanagement.htm)



Head scab or Fusarium head blight (FHB), *Fusarium* spp.

Wheat head scab or *Fusarium* head blight caused by *Fusarium* species is currently a disease of minor importance in India, but due to global climate change there are chances of having more rainy days and high precipitation during the time of anthesis which will make wheat vulnerable to head scab. During 2005, due to continuous rain in March in Punjab, head scab appeared in severe form on durum variety 'PDW 274' in Gurdaspur area of Punjab. This is a newly emerging problem in the cooler and humid areas in foothills of Punjab and Himachal Pradesh. It causes seed shriveling and white ear heads. Unfortunately, wheat cultivars in India are susceptible to FHB. The principal pathogens associated with FHB in India are *F. graminearum* and *F. semitectum*. Disease is characterized by bleaching of the wheat spike, shrivelled kernels and accumulation of mycotoxins which may cause various

Table 4. Yield gain in IPM fields compared to non-IPM at village Darar (Karnal)

Variety	Yield (Q/ha)		Increase (%)
	IPM	Non IPM	
'PBW 343'	44.0	40.0	10.0

Table 5. Yield gain in IPM fields compared to non-IPM

Variety	Yield (Q/ha)		Increase (%)
	IPM	Non IPM	
'PBW 502'	62.0	55.30	12.11 %

ailments in humans and animals. Hence vigil is needed for this disease of future importance.

Flag smut, *Urocystis agropyri*

This is a disease of limited importance, but sometimes occurs in severe form in isolated fields in NWPZ and NHZ. It forms grey to grayish black sori with silvery margins on the leaf blades which become twisted. The infected plants become sterile and do not bear any grais.

Major insect pests

The wheat crop in India is relatively free from epidemics of insect pests. However, insect pests can cause damage on a limited scale, in various parts of the country

Termites, *Odontotermes obesus, Microtermes obesi*

Termites occur mainly in the NWPZ and CZ. Damage is more under rainfed conditions. Termites attack the crop at various growth stages, from seedlings to maturity. Damage to germinating seeds leads to poor crop emergence. The severely damaged plant can be easily uprooted and look wilted and dried. In case roots are partially damaged the plants show yellowing. These insects live in colonies in special nests called termitaria, which may be above ground or underground. The pest is mainly confined to light soils and rainfed areas.

Aphids, *Sitobion avenae, Rhopalosiphum padi* and various other species

Aphids are present in almost all wheat growing areas in the country. The aphids exist in different stages, viz. winged (alates), wingless (apterous), sexual and asexual forms. The rapid spread takes place through asexual reproduction where females give rise directly to nymphs rather than eggs. Infestation occurs usually during January, till crop maturity. When populations are high, aphids cause yellowing and dessication of leaves, stems and the spike. The aphids excrete a sweet substance called "honeydew" which, when it lands on the foliage leaves a small scorch mark. Honeydew also encourages the growth of other microorganisms such as sooty mold, which often appears as a black smudgy substance on the leaf, thereby reducing the photosynthetic efficiency.

Root aphid, *Rhopalosphum rufiabdominalis*

This pest causes severe damage in some pockets in CZ during 90s especially Madhya Pradesh, is a now a regular pest in several states of NWPZ & NEPZ. This pest has shown an increasing trend in the NWPZ in the recent years. The studies have indicated the rise in temperatures and changes in production technology may favour to prolong the activity of this pest. The general observations indicate that this pest is more damaging in zero tilled wheat and the years where December first fortnight is hot. So far there were no studies on losses estimations but in case of severe damages, the losses would be in the range of 15-20%.

Army worm, *Mythimna separata*

This insect occurs mostly in the warmer climates of CZ and to some extent, in NWPZ and NEPZ. The larvae are found in the cracks of soil and hide during the day but feed during night or early morning. In wet and humid weather, they may feed during day time also. They are voracious feeders and under favorable conditions, entire fields are denuded of foliage within a few days. They survive during summer on the subsequent crops like rice and also continue to exist in rice stubbles before wheat crop comes in the field.

Brown wheat mite, *Petrobia latens*

Brown wheat mite occurs in most of the wheat growing areas, especially under rainfed conditions in Haryana, Rajasthan and Madhya Pradesh. They cause damage through sucking mouth parts. When present in large numbers, mites cause a silvery flecking on leaves. Individual mites are too small to be visible with naked eye without effort. Incidence usually starts during December-January and continues till crop maturity. Frequent winter rains and cloudy weather is not conducive for mite multiplication. Mites are also seen infesting weeds like *Cynodan dactylon*, *Vicia faba* *Fumaria indica*, *Chenopodium album* and *Convolvulus arvensis*.

Major nematodes

In wheat, crop health problems due to nematodes are limited. However, a few of them are of importance in some parts of the country and need management measures.

Cereal cyst nematode, *Heterodera avenae*

This nematode is found in most of the cereal growing regions of the country, especially, the dry and warmer areas of Rajasthan, Haryana and Punjab, but incidence is less in cooler climates. Larvae enter the roots near the growing point, especially, at the seedling stage. The roots of infected plants become predisposed to various soil borne disease like root rots. In infected fields, the losses can be considerably high.

Seed gall nematode (ear cockle), *Anguina tritici*

It is found in some parts of northern India, especially the states of Bihar, Jharkhand, eastern UP and Chhatisgarh. It is prevalent in areas where farmers recycle their seed year after year without caring for the infestation. These nematodes are spread through galls in the seed lots during planting and harvesting. Wet weather favours larval movement and

infestation. The nematode invades the crown and basal stem area, finally penetrating floral primordia. This leads to formation of nematode galls in the earheads. This pest seems to have vanished from Punjab, parts of Haryana and J&K State due to adoption of improved production technology.

Natural enemies of insect pests of wheat ecosystem

Some of the predators and parasites (beneficial insects) of the insect pests in the wheat ecosystem have been recorded during the crop health surveys (Table 1).

Management of pest problems – an integrated approach

Enough information has been generated in India on various components of IPM in managing the individual pest problems. Based on this, IPM modules have been synthesized, evaluated and validated on large scale at farmers' fields in NWPZ. Putting major focus on crop health problems like loose smut, termites and aphids, the modules have been formulated. These modules have given up to 15% higher yield than the farmers practice by integrating a reduced dosage of chemical pesticide carboxin (Vitavax 75WP) and bioagent fungus (*Trichoderma viride*), broadcast of insecticide treated soil for the control of termites and a spray of less hazardous insecticide imidacloprid (Confidor 200SL) on border rows for the control of foliar aphids. The spray of the chemical on the borders helps in controlling the population built-up of aphids for further progress inside the field and also, the populations of biocontrol agents (several species of coccinellid beetles) remain active inside the field for feeding whatever aphids enter the field. A general spray of the insecticide throughout the field would, otherwise liquidate the beneficial insects like coccinellids inside the field. The economic thresholds of different pests for taking up the spray schedule are given in Table 2 and 3.

IPM modules are location specific and sometimes, can be region specific depending upon the disease and pest problems of the area or region. Evaluation, validation and promotion of IPM modules were done under rice-wheat system under the National Agricultural Technology Programme on IPM (PSR-13 and MM-53 at five centres, viz Karnal, New Delhi, Pantnagar and Ludhiana in NWPZ and Faizabad in NEPZ. The module in wheat synthesized at Karnal was validated and promoted on large scale in three districts of Haryana.

Composition of IPM module

The IPM module being promoted is targeted at the pests like loose smut, rusts, powdery mildew, termites and aphids. This package consists of the following components:

- Seed treatment with bioagent, *Trichoderma viride* @ 4g/kg seed + carboxin (Vitavax 75 WP @ 1.25g/kg seed) or Tebuconazole (Raxil 2DS @ 1.0 gm/kg seed) to take care of loose smut disease and to have PGPR effect.
- Broadcast of endosulfan treated soil two days after first irrigation. (50 kg fine soil, mixed with 2.3 litres of endosulfan, diluted in 4 litres of water and broadcasted like fertilizer in one hectare standing wheat crop).
- Spraying of imidacloprid (Confidor 200SL @ 0.4 ml/L water) on border rows for control of aphids as soon as aphids are spotted (3-4/tiller) on the border rows
- Spraying of *Trichoderma viride* or propiconazole (Tilt 25EC or Result @ 0.1%) to control powdery mildew during the month of March (need-based).
- For management of rusts, the rust resistant varieties, 'PBW 550', 'DBW 17', 'DBW 16' (late sown) should be grown. One spray of propiconazole (Tilt 25EC@0.1%) should be given on appearance of yellow rust in old and susceptible varieties like 'PBW 343', 'HD 2687', 'PBW 502' etc. If the disease appears late, i.e. towards middle of March, the spray can be avoided. The weedicide and other cultural practices as per agronomic recommendations for the area.

The IPM in wheat was taken up in three phases. In phase-I (started in 1999-2000 crop season), eight IPM modules were synthesized and evaluated at DWR farm. Out of these, six were evaluated during the following year (2000-01) at DWR farm as well as at farmers' field of one acre size. In phase-II, the most effective module was selected and further validated at DWR farm and the farmers' fields in two villages of Karnal district (villages Traori and Darar) during 2001-02 and 2002-03. In phase-III, It was further promoted to the districts of Karnal, Kaithal and Kurukshetra in the following years. The villages were Darar and Traori (Karnal district), Mathana (Kurukshetra district) and villages Mundari, Seevan and Jhabra Dera (Kaithal district). The farmers who have been participating in the IPM programme in various villages are: Shri Mukhtiar Singh (vill. Darar, Karnal), Shri Jai Kishan Sharma (vill. Traori, Karnal), Shri Harpal Singh (vill. Mundri, Kaithal), Shri K.K. Midha and Shri Vinod Midha (vill. Seevan, Kaithal), Shri Ram Prakash (vill. Mathana, Kurukshetra) and Shri Amrik Singh and Kulwant Singh (vill. Jhabra Dera, Seevan, Kaithal). In Phase IV, from the year 2006 – 07, the IPM modules in wheat is being promoted on large scale.

The yield advantage in different villages and different varieties has been in the range of 9 to 15% consistently over the years, which has encouraged the farmers to take up this technology on large scale.

During 2008-09, the demonstrations on IPM in wheat

were conducted in village Kalri, Karnal, Haryana, at eight farmers' fields covering 25 acre area to intensify the efforts in order to convince the farmers about advantages of adoption of IPM. Variety 'PBW 502' was sown by the farmers. Data were collected for various parameters which have shown an increase in wheat yield by 12% over control.

IPM package

Based on the evaluation and validation of IPM modules and the information generated on various components, the following package of IPM practices has been standardized which can be recommended for an effective and eco-friendly management of pest or crop health problems of rice – wheat rotation in NWPZ and other areas.

At sowing time

In north Indian conditions, treat the seed with recommended fungicide (if the disease level in the seed lot is expected to be high) like carboxin (Vitavax 75WP @ 2.5 g/kg seed), carbendazim (Bavistin 50 WP @ 2.5 g/kg seed), tebuconazole (Raxil 2DS @ 1.25 g/kg seed). If the disease level in the seed lot is low (i.e. less than 5%), treat the seed with a combination of *Trichoderma viride* (4 g/kg seed) with half the recommended dose of carboxin. In case, loose smut is not a problem, the treatment with *T.* viride only @ 4 g/kg seed will help in better germination and initial vigour. The seed treatment also needs to be done in areas having problem of flag smut and foot rot. In areas having termite problem, the seed can be treated with endosulfan @ 7 ml/kg seed, along with fungicide and *T. viride* which are compatible with each other.

Seedling stage

To avoid damage due to termites, the broadcast of insecticide treated soil along with first irrigation is recommended. For this, endosulfan @ 0.8 kg *a.i./ha* is mixed in 40-50 kg of sand or fine soil along with 4-5 litres of water. This treated soil is broadcasted in the field with sufficient moisture (1-2 days) after first irrigation.

Boot leaf stage

In the Karnal bunt endemic area, the spray of propiconazole (Tilt 25EC @ 0.1%) at earhead emergence stage can be given to protect the seed crop from Karnal bunt disease. However, the spray can be avoided in case there are no rains during second week of February, i.e. coinciding with the earhead emergence stage. One spray of *T. viride* can be given at crop growth stage of 31-40, followed by one spray at 41-49, can provide non-chemical management of Karnal bunt.

One spray of imidacloprid (Confidor 200SL) @ 100 ml / hectare be given on border rows up to about five meter width to control foliar aphids, which colonize the wheat plants on borders before entering the main field.

Earhead stage

The loose smut appears at this stage. Infected plants can be identified in advance since, the leaf tip of the boot leaf shows yellowing in some of the varieties. These plants can be carefully removed and burnt.

Storage

The seed/grain should not be stored with high moisture content (>14%). Normally, the moisture content should be around 8-10% at the time of storing the grain/ seed. However, the fluctuations in grain moisture take place depending upon the atmospheric moisture level.

The studies here at the Directorate have indicated that pre-harvest spray of either malathion or cypermethrin can protect the grain in storage up to six months after harvest. Proper sanitation and cleanliness should be ensured in the godown. Also prophylactic spray of malathion @ 10 ml in one litre water at recommended dose of three litres spray solution in 100 m^2 area proves helpful in storage area prior to the storage.

SUMMARY

The IPM technology has been developed and validated at the farmers' fields in wheat. This technology is initiated only in the recent past in case of wheat. IPM has been introduced in wheat by the DWR, Karnal under four phases, covering synthesis, evaluation/ validation, large scale promotion at farmers' fields.

During the fourth phase, the Extension Unit of Directorate has taken up this technology for transfer to the farmers' fields in various districts of Haryana. Since, there are several pest problems common to rice and wheat crops and the tillage options of one crop affect the pest system in the other, it has been recommended that the IPM approach may be adopted on cropping system basis rather than individual crop basis. The yield advantages in the last decade have indicated a yield gain of about 10%.