Wheat
Cultivation in India
Pocket Guide

ICAR - Directorate of Wheat Research
Karnal - 132 001 (Haryana)

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General information

Wheat (*Triticum aestivum* L.) is the second most important cereal crop of India and plays a vital role in food and nutritional security of the country. Nearly 55 per cent of the world population depends on wheat for about 20 per cent of calories intake. It is one of the major food grains of the country and a staple food of the people of North India, where people have preference for chapatti. The diverse environmental conditions and food habits of people in India supports the cultivation of three types of wheat (bread, durum and dicoccum). Among these, bread wheat is contributing approximately 95 per cent to total production while another 04 per cent comes from durum wheat and close to one per cent from *Dicoccum*. Wheat crop in India is grown under six diverse agro-climatic zones (Table 1), wherein Indo-Gangetic Plains (IGPs) comprising the two zones namely; North Western Plains Zone (NWPZ) and the North Eastern Plains Zone (NEPZ) form the major wheat tract followed by the Central Zone (CZ) and the Peninsular Zone (PZ).

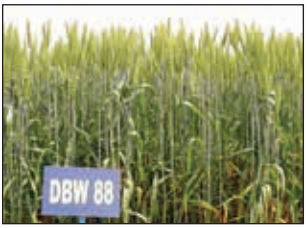


Table 1. Classification of wheat growing zones in India

Zone	Region/State	Area (m. ha)
Northern Hills Zone (NHZ)	Western Himalayan regions of J&K (except Jammu and Kathua distt.); H.P. (except Una and Paonta Valley); Uttaranchal (except Tarai area); Sikkim and hills of West Bengal and N.E. States	0.9

North Western Plains Zone (NWPZ)	Punjab, Haryana, Delhi, Rajasthan (except Kota and Udaipur divisions) and Western UP (except Jhansi division), parts of J&K (Jammu and Kathua distt.) and parts of HP (Una distt. and Paonta valley) and Uttarakhand (Tarai region)	11.5
North Eastern Plains Zone (NEPZ)	Eastern UP, Bihar, Jharkhand, Odisha, West Bengal, Assam and plains of NE States	11.9
Central Zone (CZ)	Madhya Pradesh, Chhattisgarh, Gujarat, Kota and Udaipur divisions of Rajasthan and Jhansi division of Uttar Pradesh	5.0
Peninsular Zone (PZ)	Maharashtra, Karnataka, Andhra Pradesh, Goa and plains of Tamil Nadu	1.8
Southern Hills Zone (SHZ)	Hilly areas of Tamil Nadu and Kerala comprising the Nilgiri and Palni hills of southern plateau	0.1
	Total	31.2

This classification of zones has been based on climatic conditions, soil types and growing duration of wheat. During wheat growing season, the expected changes in climatic factors viz; precipitation/winter rains, minimum and maximum temperature, wind velocity and its direction, sunshine hours etc. need to be considered in choosing modern varieties and matching production and protection technologies that are developed specifically to mitigate the possible anticipated effects of climate change.

Wheat production technology

This small pocket guide has collection of required information about the choice of wheat varieties, matching agronomic practices to be followed by the farmers and also some of the common problems related to crop protection issues that could limit wheat production and productivity at regional or farm level. Besides, the wheat growers are advised to keep track of the latest technologies on wheat and adopt these to enhance wheat productivity, and reduce cost of production so as to increase profit on sustainable basis.

Choice of variety

At present, good choice of improved varieties is available to farmers for growing under different production conditions.

Table 2. Choice of wheat varieties for different zones and production conditions in India

Zone	Production condition	Varieties	Yield (q/ha)	
			Range	Average
Northern Hills Zone (NHZ)	TS-IR-high fertility	HPW 349, HS 507, VL 907, VL 804, VL 738*	37.5-42.5	40.5
	TS-RF-low fertility	HPW 349, HS 507, VL 907, SKW 196*, VL 804, VL 738*, TL 2969 (trit), TL 2942 (trit)	27.5-31.4	29.3
	ES-RF-low fertility	HS 542, HPW 251, VL 829	27.7-40.5	35.5
	LS-RI-medium fertility	VL 892, HS 490, HS 420	26.1-34.1	30.7
	High altitude areas	VL 832, HS 375	12.6-15.1	13.7

North Western Plains Zone (NWPZ)	TS-IR-high fertility	DBW 88, HD 3086, WH 1105, HD 2967, DPW 621-50, PBW 550*, DBW 17*, WHD 943(d), PDW 314 (d), PDW 291 (d)	47.9-53.9	51.7
	LS-IR-medium fertility	DBW 90, WH 1124, DBW 71, HD 3059, PBW 590, WH 1021, DBW 16, WR 544 (VLS), RAJ 3765*	38.9-44.5	41.8
	TS-RF/RI-low fertility	PBW 644, WH 1080, HD 3043, PBW 396	26.3-36.9 (RF) 35.0-50.8 (RI)	33.7 44.6
North Eastern Plains Zone (NEPZ)	TS-IR-high fertility	NW 5054, K 1006, DBW 39, CBW 38, Raj 4120, K 307, HD 2824, HD 2733, PBW 443, HUW 468, NW 1012	40.8-47.7	45.5
	LS-IR-medium fertility	HD 2985, HI 1563, NW 2036, HW 2045, DBW 14, NW 1014, HD 2643	38.0-41.7	39.8
	TS-RF-low fertility	HD 2888, MACS 6145	23.4-27.5	24.7
Central Zone (CZ)	TS-IR-high fertility	MP 3288, HI 1544, GW 366, GW 322, GW 273, HI 8713 (d), MPO 1215 (d), HI 8498 (d)	51.0-54.5	53.1
	LS-IR-medium fertility	MP 3336, Raj 4238, MP 1203, HD 2932, HD 2864, MP 4010	46.3-48.6	47.2
	TS-RF-low fertility/RI	MP 3288, MP 3173, HI 1531, HI 8627 (d), HI 1500, HD 4672 (d), HW 2004 (Amar)	19.8-23.6 (RF) 30.4-40.0 (RI)	22.0 36.6

Peninsular Zone (PZ)	TS-IR-high fertility	MACS 6478, UAS 304, MACS 6222, NIAW 917, Raj 4037, GW 322, HUW 510, UAS 428 (d), UAS 415 (d), MACS 2971 (dic), HI 8663(d), DDK 1029 (dic), DDK 1025 (dic)	40.0-45.7	42.3
	LS-IR-medium fertility	HD 3090, AKAW 4627, HD 2932, Raj 4083, PBW 533, HD 2833	33.1-38.4	35.4
	TS-RF-low fertility/RI	NIAW 1415, HD 2987, PBW 596, HD 2781, K 9644, AKDW 2997-16 (d)	12.3-16.5 (RF) 20.3-27.0(RI)	14.4 23.2
Southern Hills Zones (SHZ)	TS-RI-medium fertility	HW 5216, HW 2044, HW 1098 (dic), HW 1085, COW (W) -1	31.7-40.9	37.0
Marginal areas	Salinity-alkalinity condition	KRL 210, KRL 213, KRL 19	27.3-36.0	32.0

Where, TS=Timely Sown, LS=Late Sown,VLS= Very Late Sown, ES=Early Sown, IR=Irrigated, RF=Rainfed, RI=Restricted Irrigation, (d) = Durum, dic.=Dicoccum and trit = Triticale.

*indicates stripe rust susceptibility and thus must be avoided in prone areas.

Besides, the information on soil health for individual farm(s) needs to be generated for minimizing input costs and maximizing yields. The stakeholder can follow latest technologies in order to mitigate local problems and thus fulfill their dreams of enhancing farm profitability in a cost effective and environment friendly manner. The information provided would be as useful tips that could be suitably applied to all the given situations across zones and production conditions. In addition, the planners, managers and carriers of technology (extension workers) at every level can also update themselves with the latest know-how and play their role in enhancing wheat production in the country.

Agronomic practices

In addition to the varietal improvement, adoption of appropriate crop management practices of fertilization, irrigation; weed management, crop geometry and crop residue management in wheat based crop sequences in various wheat growing zones have significantly contributed in harnessing the yield potential of new varieties. To cut down the cost of wheat production without compromising on yield, the zero-tillage technology has been perfected for wheat cultivation.

Other forms of resource conservation technologies (RCTs) which are also gaining momentum include rotary-tillage and furrow irrigated raised beds (FIRBs) technology. The rotary tillage technology saves about 80 per cent diesel but has given

higher yields over zero tillage as well as conventional tillage. Recently, new machines (Turbo seeder & Rotary disc drill) have been fabricated to seed into surface retained crop residues which is otherwise being burnt causing environmental pollution and loss of essential plant nutrients.

Sowing time, seed rate and fertilizer application: The wheat crop in India is grown across six agro-climatic zones and production conditions. The time of sowing has slight variation from zone to zone and under varying production conditions. To realize best yields under any situation, timely sowing and following recommended agronomy is the most important key factor to make best use of inputs and technology. The information for the commercial cultivation of wheat crop under different systems is given in Table 3.

Approaches for improving soil health: The intensive tillage coupled with crop residue burning and continuous mining of soil has led to the depletion of soil organic matter as well as essential plant nutrients. The situation is further complicated by imbalanced fertilization leading to expression of multiple nutrient deficiencies. The Zn is already recommended and there are more frequent occurrence of deficiencies of Mn, Fe, Cu, Mo and B in the rice-wheat system. More than 35% soils are also deficient in sulphur and the K status has also reached a threshold in many soils since farmers are mainly applying nitrogen and phosphorus

Table 3. Zone-wise sowing time, seed rate and fertilizer dose for wheat crop

Zone	Sowing conditions	Seed rate	Fertilizer doses and time of application
NHZ	Irrigated, timely sown (1-15 Nov.)	100 kg/ha	120:60:40 kg NPK /ha (1/3 N and full P&K as basal at sowing and remaining N in two equal splits at first and second irrigation)
	Irrigated, late sown (After 25th Nov.)	125 kg/ha	90:60:40 kg NPK /ha (1/3 N and full P&K as basal at sowing and remaining N in two equal splits at first and second irrigation)
	Rainfed	125 kg/ha	60:30:20 kg NPK/ha to be applied at the time of sowing
NWPZ and NEPZ	Irrigated, timely sown NWPZ: 1-15 Nov. NEPZ: 10-20 Nov.	100 kg/ha	150:60:40 kg NPK /ha (1/3 N and full P&K as basal at sowing and remaining N in two equal splits at first and second irrigation)
	Irrigated, late sown (After 25th Nov.)	125 kg/ha	120:60:40 kg NPK /ha (1/3 N and full P&K as basal at sowing and remaining N in two equal splits at first and second irrigation)
	Rainfed	125 kg/ha	60:30:20 kg NPK/ha to be applied at the time of sowing
CZ, PZ and SHZ	Irrigated, timely sown CZ: 10-20 Nov., PZ: 1-15 Nov. SHZ: Mid Nov.	100 kg/ha	120:60:40 kg NPK /ha (1/3 N and full P&K as basal at sowing and remaining N in two equal splits at first and second irrigation)
	Irrigated, late sown CZ & SHZ: 1-15 Dec. PZ: Last week of Nov.-1st week of Dec.	125 kg/ha	90:60:40 kg NPK /ha (1/3 N and full P&K as basal at sowing and remaining N in two equal splits at first and second irrigation)
	Rainfed	125 kg/ha	60:30:20 kg NPK/ha to be applied at the time of sowing

to the crops. Following strategies may help in reversing the adverse effects on soil;

- Adoption of resource conservation technologies like zero tillage and conservation agriculture - Minimum soil disturbance to conserve soil organic matter.
- Residue management - Incorporation or surface residue retention to enhance the soil organic matter.
- Developing new and improving the available machinery for residue management and conservation agriculture.
- Introduction of leguminous crops like moong bean to regain & build up the soil health.
- Green manuring to increase soil organic matter.
- Balanced use of fertilizers-Application of NPK in proper proportion along with FYM and need based application of Zn, Mn, Fe, Cu, Mo and B as micro-nutrients for optimum yields.

Application of micronutrients

Zinc sulphate at the rate of 25 kg/ha once in a year or 10 kg/ha to each crop during rabi and kharif season should be applied in areas where its deficiency is prevalent. If zinc deficiency symptoms are visible in the crop then spray 0.5 % zinc sulphate solution. For this, dissolve 2.5 kg zinc sulphate and 1.25 kg unslaked lime or 12.5 kg urea in 500 litres of water for one hectare and spray it 2-3 times at 15 days interval.

In areas having manganese deficiency, spray 0.5% solution of $MnSO_4$. Dissolve 2.5 kg $MnSO_4$ in 500 liter of water. First spray should be done 2-5 days before first

irrigation and remaining 2-3 sprays at one week internal. Spray should be done during clear and bright sunny day. In case of sulphur deficiency, soil application of sulphur or spray application can be resorted for correcting deficiency. When zinc sulphate or gypsum is applied, sulphur deficiency is taken care off. Where only sulphur deficiency is prevailing apply Cosavet 80WDG @ 8-10 kg/ha at the time of sowing or just before first irrigation.

Weed management: Wheat is infested with both grasses and broad-leaved weeds. For realizing full yield potential of wheat crop the proper weed control is essential. Among various methods of weed control chemical method is most effective. Based on weed flora following herbicides can be applied.

- In areas having the problem of Isoproturon resistant *P. minor* use Sulfosulfuron, or Clodinafop or Fenoxaprop or Pendimethalin or Pinoxaden. Sulfosulfuron and Pendimethalin are effective against both grassy and non-grassy weeds whereas, Clodinafop, Fenoxaprop, and Pinoxaden are specific to grasses. Whereas, areas infested with multiple herbicide resistant *P. minor* (resistant to Isoproturon, Clodinafop and Sulfosulfuron) use pre-emergence Pendimethalin.
- For the control of complex weed flora combination of herbicides should be applied. Sulfosulfuron + Metsulfuron and Isoproturon with 2,4-D or Metsulfuron can be used as tank mixture.

Table 4. Options for herbicides to control different types of weeds

Weed flora	Herbicides	Dose (gm a.i. /ha) Product dose (g or ml/ha)	Time of application DAS
Grasses: *Avena ludoviciana* (Wild oat/Jangali Jai); *Phalaris minor* (Mandusi/Kanki); *Polypogon monsplensis* (Lomar ghas) *Poa annua* (Poa grass)	Clodinafop (Topik 15WP)	60 (400)	Post emergence 30-35 DAS
	Fenoxaprop-ethyl (Puma Super 10EC)	100-120 (1000-1200)	Post emergence 30-35 DAS
	Pinoxaden (Axial 5 EC)	40-50 (800-1000)	Post emergence 30-35 DAS
	Sulfosulfuron (Leader 75 WG)	25 (33.3)	Post emergence 30-35 DAS
	Isoproturon (Arelon 75 WP)	1000 (1333)	Post emergence 30-35 DAS
	Pendimethalin (Stomp 30EC)	1000-1500 (3333-4950)	Pre-emergence 1-3 DAS
Broad-leaved weeds: *Chenopodium album* (bathua); *Chenopodium murale* (Kharbathu); *Rumex dentatus* (Jangali palak); *Medicago denticulata* (Maina); *Melilotus indica* (Senji/Metha); *Malva parviflora* (Malva/Sonchal); *Solanum nigrum* (Makaoi); *Convolvulus arvensis* (Hirankhuri); *Asphodelus tenuifolius* (Pyaji); *Vicia sativa* (Chatri); *Lathyrus aphaca* (Matri); *Anagallis arvensis* (Krishnaneel); *Coronopus didymus* (Pitpapra); *Circium arvense* (Kandai)	2,4-D-E (Weed Mar 38 EC)	500 (1315)	Post emergence 30-35 DAS
	Metsulfuron (Algrip 20 WP)	4 (20)	Post emergence 30-35 DAS
	Carfentrazone (Affinity 50 WDG)	20 (50)	Post emergence 30-35 DAS
	Pendimethalin (Stomp 30EC)	1000-1500 (3333-4950)	Pre-emergence 1-3 DAS
Both grassy and broad-leaved weeds	Sulfosulfuron (Leader 75 WG)	25 (33.3)	Post emergence 30-35 DAS
	Pendimethalin (Stomp 30EC)	1000-1500 (3333-4950)	Pre-emergence 1-3 DAS
	Isoproturon (Arelon 75WP)+2,4-D E	750 + 500 (1000+1315)	Post emergence 30-35 DAS
	Sulfosulfuron+ Metsulfuron (Total 80WG)	30 + 2 (40)	Post emergence 30-35 DAS

Grass herbicides (Clodinafop, Fenoxaprop and Pinoxaden) should not be tank mixed with either 2,4-D or Metsulfuron and to avoid antagonism the grass and broad-leaved herbicides should be applied sequentially.

Water management: Water is becoming a limiting factor in wheat production all over the country and irrigation scheduling is followed depending on the availability of water. Excess utilization of ground water in dry areas has led to depletion of underground water and farmers are expecting to get reasonable grain yield with sub optimal irrigation. Through restricted irrigation (a single post sown irrigation under rainfed condition), can double the grain yield of many of the wheat genotypes.

The normal practice of applying four to six irrigations (28-42 cm-ha water) are enough for wheat crop. However, crown root initiation and flowering stages are the most critical to moisture stress. Depending upon the water availability, irrigation should be applied as per the schedule.

In case of very light soil as well as area having undulating topography, sprinkler method of irrigation should be used. Also in light soil and in area having water scarcity, bed planting techniques can be adopted as it saves 30% water. Further, Laser land leveling must be popularized on large scale as it will help in

Table 5. Irrigation scheduling (number and stage) depending on amount of water availability

Water Availability	Crown root initiation (21 DAS)	First node (45 DAS)	Jointing (65 DAS)	Boot (85 DAS)	Milk stage (105 DAS)	Dough (120 DAS)
1 Irrigation	√					
2 Irrigations	√			√		
3 Irrigations	√		√		√	
4 Irrigations	√	√	√		√	
5 Irrigations	√	√	√	√	√	
6 Irrigations	√	√	√	√	√	√

improving the input use efficiency particularly of water and nitrogen.

The injudicious use of fertilizers and water has led to numerous problems such as deteriorating soil health and receding water table. Therefore use of NDVI sensors and micro-irrigation for efficient nitrogen and irrigation water management, respectively coupled with adoption of conservation agriculture practices can help increase the crop productivity as well as improvement of natural resource base for long term sustainability.

Crop protection

The host resistance is the cheapest, effective and environmental friendly means of management of diseases and pests. The disease scenario of different zones varies but the problem of yellow rust disease which is prevalent in northern and southern hills, north western and north eastern plains of the country is a major cause of concern.

Rust: In NWPZ and NHZ, stripe rust (yellow rust) is very important. For avoiding the losses due to stripe rust of wheat in NWPZ, varieties like DBW 88, WH 1105, HD 2967, DPW 621-50, WH 542, PBW 550, PDW 314 (d) and WHD 943 (d) for timely sown and DBW 16, DBW 90, DBW 71, PBW 590, WH 1021 and HD 3059 for late sown conditions may be preferred. In NHZ, varieties like HPW 349, HS 507, HS 365, HS 375, VL 616, VL 907, VL 829, VL 832, VL 892, HPW 155, SKW 196 etc. should be grown.

Yellow rust (Stripe rust)

Usually, it is observed that the early infection of stripe rust starts in wheat fields under the poplar trees wherever these are grown having early sown crop (i.e. October). Hence, strict watch is needed by the farmers in such fields.

Since most of the varieties recommended for NWPZ and NHZ do not carry high level of resistance, hence, chemical sprays are needed. Spray the crop with Propiconazole (Tilt 25 EC @ 0.1 per cent), or Tebuconazole (Folicur 250EC @ 0.1%) or Triademefon (Bayleton 25WP @ 0.1%) at stripe rust initiation using 200 litre of water/ha. Usually, it is required in the first half of February.

Black rust (Stem rust)

Stem and leaf rusts are the major diseases of wheat in CZ, PZ and SHZ. From rust epidemiology

point of view, for disrupting the *Puccinia* path, following rust resistant varieties are required to be grown in respective zone.

Brown rust (Leaf rust)

Central Zone (Madhya Pradesh, Chhattisgarh, Gujarat)

Timely sowing: HI 1544, GW 322, DL 803-3, MP 3288, HI 8498 (durum) and HD 4672 (durum)

Late sowing: MP 1203, HD 2864, HD 2932 and Raj 4083

Peninsular Zone (Maharashtra, Karnataka)

Timely sowing: MACS 6222, Raj 4037, GW 322, HUW 510, HD 2189, MACS 2971 (dicoccum) and HD 8663 (durum).

Late sowing: AKAW 4627, HD 2932, HD 2833, Raj 4083 and PBW 533.

Southern Hills Zone (Tamil Nadu)

HW 2044, HW 1085, Co(W)-1.

In the same way, loose smut and powdery mildew disease of wheat is very well managed through seed treatment and spray of recommended fungicides, respectively. Nevertheless, in view of decreasing water table and increasing temperature, both termites and aphids may become prominent threats to wheat crop in future.

Loose smut: Loose smut is a seed borne disease. In view of the horizontal distribution of the seed material among the farmers and the use of the carry over seed, effective control measures for lose smut should be undertaken. For this, seed treatment with Carboxin (75 WP @ 2.5 gm/kg seed) or Carbendazim (50 WP @ 2.5 gm/kg seed) or Tebuconazole (2DS @ 1.25 gm/kg seed) or a combination of a reduced dosage of Carboxin (75 WP @ 1.25 gm/kg seed) and a bioagent fungus *Trichoderma viride* (@ 4 gm/kg seed) is recommended.

Integrated management of loose smut involving reduced dosage of chemical fungicide and bioagent fungus is more eco-friendly and equally effective as the chemical control measures and thus should be preferred. Use of bioagents also helps in improving the initial vigour of the crop. Seed treatment with fungicide should be done one or two days before sowing. In case of integrated management, the treatment with *T.viride* should be done 72 hours before sowing, followed by the fungicide, 24 hours before sowing.

Karnal bunt: Karnal bunt (KB) control is required for seed crop and the produce grown for export purposes. For producing KB free wheat, farmers are

advised to grow KB resistant varieties recommended for the respective area.

- In NWPZ, PBW 502, PDW 233 and WH 896 should be grown.
- In areas where Karnal bunt incidence is low, by growing durum wheat for 2-3 years, fields can become free from Karnal bunt pathogen, *Tilletia indica*.
- Zero tillage helps in reducing Karnal bunt incidence.
- Avoid irrigation at heading time.
- One spray of Propiconazole 25EC (Tilt 25 EC) @ 0.1 per cent using 200 litre of water be given at 50% flowering. If conditions are favourable for the disease then repeat at an interval of 15 days to control the disease.
- In KB prone areas, the seed crop can be given one spray of Propiconazole or two sprays of *T.viride* at tillering and ear head emergence stage.

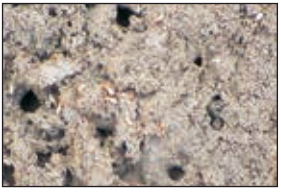
Powdery mildew: For the control of powdery mildew in disease prone areas, one need-based spray of Propiconazole (Tilt 25 EC @ 0.1%) can be given at ear head emergence or appearance of disease on flag leaf, whichever is earlier.

Foliar blight: Foliar blight is the main crop health problem in NEPZ. For effective management of the diseases, cultivation of recommended (resistant) varieties, like HD 2985, HI 1563, DBW 39, CBW 38, NW 1014,

NW 2036, K 9107, HD 2733 (resistant to LB), DBW 14, HD 2888, K0307, DBW39 and HUW 468 should be encouraged.

Flag smut: Flag smut disease also poses problems in isolated fields in Punjab, Haryana, Rajasthan and some other parts of NWPZ. Disease management measures taken for the control of loose smut disease (as discussed above), proved to be effective against flag smut too. Hence, seed treatment with Carboxin or Tebuconazole may be followed in fields with flag smut history.

Termite: In the termite prone areas, seed treatment with Chlorpyriphos @ 0.9g a.i /kg seed (4.5 ml product dose / kg seed), be taken up for their management. Seed treatment with Thiamethoxam 70WS (Cruiser 70WS) @ 0.7 g a.i./kg seed (4.5 ml product dose/kg seed) or Fipronil (Regent 5FS @ 0.3 g a.i./kg seed or 4.5 ml product dose /kg seed) is also very effective. In the standing crop, the broadcasting of the insecticide treated soil 15 DAS be practiced. For this, Chloropyriphos 20EC @ 3 l mixed in 50 kg soil be used for one hectare field. Crop planted under raised beds is more prone to termite attack in the termite-prone areas, while zero tillage shows less termite damage. Hence, proper attention should be given in crop planted on raised beds.



Aphids: For the management of aphids, foliar spray of Imidacloprid 200SL @20g a.i./ha on border rows at the start of the aphid colonization be given. This will help in protection of the bioagent insect, the lady bird beetle inside the field which feeds on aphids.

Pink stem borer: The incidence of pink stem borer is observed more in fields of rice-wheat cropping system where wheat is sown in zero tillage fields. For its management, foliar spray of Quinalphos (Ecalux) 2000 ml/ha as soon as pink stem borer is seen. Irrigation also helps in reducing the pink stem borer damage.

Ear cockle: Ear cockle is an important disease in eastern parts of India, hence proper precautions be taken, especially in eastern U.P., Bihar and Jharkhand. Wider publicity should be given by extension agencies on the use of gall-free seed, well before the sowings. Farmers should adopt floatation technique for the separation of galls from the infested seed lots. The infested seed lot should be floated in 2 percent brine solution for this purpose. The galls will float on the surface. These should be separated

and destroyed away from the field by burning. The seed should be thoroughly washed to remove the salt solution before sowing.

IPM module: The IPM module developed and validated in NWPZ can be adopted in parts of north-west plains zone. This involves the seed treatment with *T.viride* (@4g/kg seed) + Carboxin (Vitavax75WP @1.25g/kg seed) or Tebuconazole (@ 1.0g/kg seed) for the control of loose smut, followed by broadcast of insecticide treated soil (with Chloropyriphos @ 3l/ha) at 15 DAS for termites.

General tips

- Choose the best suitable variety for your area and condition.
- Follow timely planting and avoid delay in sowing of wheat crop to avoid yield losses due to adverse effects of heat around maturity.
- Do not grow varieties from other zones to avoid risk of disease susceptibility.
- Manage your crop with optimum inputs (fertilizer, irrigation water, herbicides, fungicides) for maximum yield.
- Timely and judiciously irrigate fields to save water and cut costs.
- Harvest crop at proper maturity to minimize risk due to shattering, threshing etc.
- Follow proper storage practices for wheat produce to avoid post-harvest losses.

New production technologies for resource conservation

Laser land levelling

Generally, fields are not properly levelled leading to poor performance of the crop, because part of area suffers due to water stress and the other parts due to excess of water. Laser land levelling is the fore most requirements for the adoption of any of the resource conservation technologies. It is a process of smoothening the field within ± 2 cm from the average elevation of the field using laser equipped bucket, which scraps from higher places and spread onto the low lying areas. After laser levelling the field, yield increase has been observed. The higher yields are due to proper crop stand, uniform fertilizer and water distribution, crop growth, uniform maturity and increased cultivable area by 3 to 6 per cent due to reduction in area under bunds and channels. In addition to higher yield, the savings of water is 35-45 per cent due to higher application as well as use efficiencies and increased nutrient use efficiency by 15-25 per cent. In recent years, the adoption of laser levelling by the farmers has gained momentum due to evident benefits of this technology right in the first crop. The price of this machine is around ₹ 3.5 lakhs which is not within the reach of every farmer and hence has to be used on custom hire basis.

Zero tillage

Zero tillage (ZT) sowing of wheat is a profitable resource conservation technique. In this technology, wheat seed and fertilizers are directly placed at proper depth into the undisturbed soil after rice harvesting using a specially designed machine which creates narrow slits by the knife type furrow openers of zero tillage ferti-seed drill instead of shovel type furrow opener in conventional ferti seed drill. The money and time to be spent in field preparation are saved by using this machine. Both timely and late sowing of wheat is possible by this method and in case of late sown even sowing can be advanced by 7-10 days. Seed rate, fertilizer doses and other package of practices in ZT should be the same as in conventional method to get good yield. Apply ⅓ or even lesser N, full P & K at sowing and the remaining nitrogen in two equal splits at first and second irrigation. Avoid planking after sowing of wheat by this machine. The cost effectiveness and development of resistance against 'isoproturon' in *Phalaris minor* was also responsible for ZT adoption in rice-wheat system due to lower incidence of this weed under ZT. Incidence of Karnal bunt and termite has also been reported to be less in ZT. This machine can sow about two acres of wheat in one hour. The carbon dioxide emission due to burning of fuel (assuming 2.6 kg CO_2 production/ litre of diesel burnt) during field preparation is about 208 kg/ha in conventional tillage where as in zero tillage it is only around 16 kg/ha.

Advantages

- Saving of time, drudgery, water, labour, money and energy as well as less wear and tear of machinery.
- Helps in advancing the sowing of wheat by 7 to 10 days which is very useful especially under late sown conditions where basmati rice/ cotton/ sugarcane harvesting is delayed beyond 25th November.
- This technology provides an opportunity to save more than ₹ 3000 per hectare in cost of cultivation thereby increasing the profit margin of the farmers
- Very less chances of lodging, less diseases especially Karnal bunt and powdery mildew as well as lower infestation of weeds like *phalari minor*.
- Yield is either same or higher (5-10%) than conventional method especially in sodic soils where water logging is a problem as well as areas where sowing of wheat is late.

Rotary tillage

Rotary tillage is an important resource conservation technology which facilitates field preparation and placing of seed and fertilizer in a single pass. The rotary till drill has six L-shaped blades on each gang which completely pulverises soil. Seed rate and fertilizers doses are similar to conventional method. This machine is also very effective for incorporation of dhaincha into soil as green manuring crop. It can also be used for single pass

puddling of paddy field after removing the drilling mechanism. This machine can cover about one acre area in one hour.

Advantages

- Rotary tillage also saves time, labour and energy and reduces drudgery in field preparation compared to conventional method.
- There is a saving of more than ₹ 2500/- per hectare in field preparation.
- If drilled, rotary tillage always gives yield advantage of 5 to 10 per cent than conventional and zero tillage technologies.
- Advances sowing of wheat by 3 to 5 days.

Bed planting

Levelling of field is a pre condition for the success of this technology. The field preparations, bed formation, placement of fertilizer and sowing of seed is completed in one go by bed planter. Furrows are used for irrigation as well as for drainage of excess water, if there is heavy rain, during crop season. Generally 2-3 rows of wheat can be planted on the top of each bed. The top width of each bed is 40-45cm for a bed of 70-75cm with furrow of 30-35 cm. Inter cropping of sugarcane can be taken up with wheat by this technique. Crop cultivars are known to vary significantly in their performance on raised beds. The direction of sowing should be North-South so that every plant gets equal sun shine. In situations where sowing is expected to be delayed due to

pre-sowing irrigation, dry seeding can be done on raised beds followed by irrigation immediately after seeding. Light irrigation can also be given at grain filling stage, which is generally avoided by the farmers for fear of crop lodging. Growing crops on raised beds can also help in diversification of the rice-wheat system. Raised bed system also provides an option for growing intercrops like sugarcane in furrows and wheat, gram, lentil, peas, mustard and various vegetable crops on beds. Since only ⅓rd area is irrigated i.e. irrigation is applied in furrows, there is substantial saving of irrigation water.

Advantages

- Saves 20-25 percent seed i.e. 30 to 32 kg/acre seed is sufficient for sowing.
- Although there is no saving on the cost of land preparation or time but if same beds are used for seeding next crop; the saving similar to rotary tillage can be made as seeding & shaping of beds can be done in a single operation.
- Suitable for seed production because of production of bold grain and easy rouging by moving in furrows to uproot unwanted plants.
- It reduces the herbicide dependence due to possibility of mechanical weed control with the same bed planter fitted with inter culture tynes with simultaneous placement of fertiliser.
- Nitrogen use efficiency is higher because of light irrigation and top dressing or placement on beds leading to fertilizer nitrogen saving by about 25%.
- Similar yield as in conventional tillage with substantial saving of seed, fertilizer nitrogen and irrigation water.

Seeding into loose residues

In NWPZ, farmers generally burn the paddy straw which causes air pollution, reduces soil biodiversity, lowers fertility, loss of precious organic carbon and nutrients. The retention of residue on soil surface has many benefits as it reduces weeds, conserves moisture, moderates soil temperature and improves soil health. Keeping the above facts in view, two machines were developed to discourage burning namely; Rotary Disc Drill and Turbo Happy Seeder which are discussed below.

Turbo happy seeder

The turbo happy seeder was developed at PAU Ludhiana under ACIAR-PAU project. This machine works on rotary mechanism and cuts the residue in front of the tynes, places seed and fertiliser using zero till machine and push the chopped straw through the tynes on to the seeded area. This machine is capable of seeding into the loose residue load of up to 10 t/ha. This machine can cover an area of one acre per hour. It requires a tractor of more than 50 HP with a dual clutch.

Rotary disc drill (RDD)

The rotary disc drill was developed at DWR, Karnal under NATP project on mechanization of rice-wheat system, for sowing of wheat into loose straw. It has been found effective for seeding into loose crop residues. This machine is also based on the rotary till mechanism. The rotor is a horizontal transverse shaft

having flanges fitted with straight discs for cutting effect similar to the wooden saw while rotating. The rotary disc drill is mounted on the three point linkage system and is powered through the power take-off (PTO) shaft of tractor. The rotating discs cut the residue and simultaneously make a narrow slit into the soil to facilitate placement of seed and fertilizer using an offset double disc assembly. Rotary disc drill is more versatile and works under almost all the situations like paddy, cotton, bajra, arhar, sugarcane ratoons with full trash for seeding crops without tillage. Compared to normal zero till drill, rotary disc drill causes minimal soil disturbance. However, it must be remembered that in the presence of loose residues, combination of rotary disc with coulter double disc completely avoids the raking problem of residues during seeding operations.

Both these machines have problems like turbo happy seeder doesn't work when residue is wet or completely loose and rotary disc drill has problem of frequent blunting of front powered discs. These problems must be addressed to make these machines more acceptable.

Harvesting, threshing and storage

When the moisture level of grain is 25% it is the proper time for manual harvesting. Generally wheat is manually harvested but for quick harvesting, combine harvester should be used to avoid losses in grain yield due to shattering and lodging. Wheat should be harvested 4-5 days before it is dead ripe. In NWPZ, due to synchronized

maturity of wheat, combine harvesting is done. Morning is the best time for harvesting. In case of manual harvesting, bundles are made and dried for 3-4 days and threshed by thresher. Before storage, grain should be dried by spreading on tarponline plastic sheets in bright sunlight to a moisture level below 12%. For storage, use bins and silos made of GI sheets. Now a days, aluminium bins, Pusa bins, silos and poly lined bags are available for storage. Farmers can store wheat grains in their traditional storage as well. To protect from storage insects, pests, it is necessary to fumigate with EDB 5 g/tons and keeping room sealed for 24 hours Farmers can also apply aluminium phosphide @ 3 g/ton.

Costs and returns

There is a wide variation in operational costs, gross returns, profit and also the cost of production in different states of India (Table 6). The difference in costs and other parameters might be due to several associated factors that vary across states. The gross return per hectare was the maximum in Haryana followed by Punjab, Rajasthan, Uttar Pradesh and Madhya Pradesh. The estimated average operation cost for the country was ₹ 25054/ha and net return was ₹ 33915/ha. The cost of production for one quintal wheat was ₹ 730.

Table 6. State wise costs and returns for wheat in India during 2012-13

State	Operational Costs (₹/ha)	Gross Returns (₹/ha)	Profit (₹/ha)	Cost of Production (₹/Qtl)
Haryana	20826	80566	59740	432
Madhya Pradesh	11170	45328	34158	435
Punjab	18058	75614	57555	362
Rajasthan	27846	61861	34015	727
Uttar Pradesh	21310	47886	26576	533
India	25054	58969	33915	730

4 W & 1 H of wheat cultivation

What to do?	When to do?	How to do?	Why to do?	What not to do?
Soil testing	October / after harvesting of crop.	Take samples from all corners and middle of field and mix well. Draw 500 gm soil sample from it and get it tested in nearby soil testing laboratory.	It will give information about soil fertility of the particular field so that one can apply fertilizer as per soil requirement / recommendations.	Don't collect the soil sample from heap of the compost /residue / standing crop to get the accurate results.
Field preparation	Field preparation should starts from October by good ploughing followed by planking for moisture conservation field should be well leveled so use Laser Land leveler for leveling the field which is quite beneficial.	Field should be well prepared by disc harrow and cultivator as per requirement of the soil. Land laser leveler can be used for perfect land leveling. It can be arranged from nearby source, if not available in the village.	Good field preparation will help in weed control. Irrigation will be uniform and saving of irrigation water in the leveled field.	To conserve soil moisture, there should not be deep/ heavy cultivation. If sowing is to be done by zero tillage, then harrow cultivation should be avoided.
		Three four field preparation operations should be done and then do leveling through planker.	Irrigation will be faster and saving of irrigation water in the raised bed field.	In heavy soils, avoided bed planting due to clod formation & crop stubbles may affect germination.

Sowing method	If there is loose straw in the field use rotary disc drill/ Happy seeder. If there is sufficient moisture after paddy harvesting use both the machines for wheat sowing.	Sowing is to be done by drilling seed and fertilizer. Seed and fertilizer pipes should be checked carefully during drilling operation.	By keeping crop residues in field weeds can be controlled. Residue retention helps in conserving moisture and increases soil organic matter.	Do not burn crop residues. By burning the crop residues beneficial insets may die. There is no need to proper field in zero tillage seeding.
Selection of improved varieties.	In October	Selection of recommended / suitable varieties should be done through discussion with the representative of research centre/ state agriculture department / friends etc.	It will increase productivity of the crop and good quality may fetch higher prices in the market.	Don't use old varieties. Such as PBW 343, UP 2338, Lok 1, HD 2687, HD 2329, WH 711, HUW 234, UP 262, WH 147 as they have become susceptible to yellow rust disease.
Balanced and integrated use of fertilizers N:P:K in 4:2:1 ratio	At the time of sowing and after the first irrigation. Micronutrients may be applied as per requirement and deficiency in the soil.	1/3 of nitrogen, full of phosphorus and potash may be applied at the time of sowing. Rest of nitrogen may be applied after first and second irrigation.	All essential nutrients are made available to the plants through balanced and integrated nutrient management application. The crop will be healthy, with higher productivity. Deficiency of one element may affect availability of other element.	Seed and fertilizer should not be placed at the same place in the soil, it will affect germination adversely and productivity will be less. So fertilizers should be placed deeper than seed if sown with seed cum fertilizer drill.

Irrigation	The pre sowing irrigation in October followed by as per requirement and availability.	Bunds may be prepared in and around the field and field should be divided in equal parts so that irrigation may be uniform, easy and quick.	It will help in field preparation, better germination and production of bumper crop. There should be judicious use of irrigation water.	Don't apply heavy irrigation in standing crop otherwise there may be loss instead of benefit due to water logging.
Weed control	At 30-35 days after sowing.	Spray properly and use recommended doses of herbicides. Use flat fan nozel for uniform application.	There will be economic loss by weeds if their population goes beyond threshold level.	Don't mix two or more herbicides without recommendations. 2,4-D and Metsulfuran with clodinafop/ Fenoxaprop Don't use wheat seed contaminated with weed seeds. Do not under dose herbicides. Don't use same herbicide year after year in the same field.
Use of resistance varieties	October -November	Procure healthy seed from reliable sources	Use of healthy and resistant varieties prevent crop from diseases.	Don't use varieties which are not recommended, otherwise there may be danger of disease spread.

Seed treatment	At the time of sowing.	Seed treatment should be done one day before sowing. Raxil @1.0gm /kg seed or Vitavex @ 2.0gm/kg seed or Thiram+Vitavax (1:1) may be used for seed treatment for smuts. Seed treatment drum may be used for seed treatment only.	Seed treatment may give protection to soil and seed borne diseases. Germination will be better; plants will be healthier and have capacity to fight against diseases.	Don't sow seed without seed treatment otherwise smuts (covered and loose) may cause heavy losses.
Treatment against termite, aphid, Karnal bunt and powdery mildew	3-4 days after first irrigation	chloropyriphos 20EC @ 3 Litre mixed in 50 Kg soil be used for one hectare field. There should be optimum moisture in the field so that the chemical may go in to the soil and control termite.	Broadcast pest treated sand/ soil to avoid termite damage.	Don't use termite treatment if it is not required. Do not apply termite treatment, if sufficient moisture in not available in soil.
Aphid control	Only after visual appearance of aphid at the borders of the field	To control aphid, apply Imidachloprid (Confidor 200 SL) @15 ml in 35 L water. The application should be around the borders 2-3 meters inside the field	There is loss due to aphid attack in wheat crop	Don't broadcast the chemical for aphid control in whole field. It may affect the friendly pest like "lady bird beetle". It is important that beneficial insects remain active inside the field.

Harvesting	Manual harvesting is done when the grain moisture is 20 percent. Use combine harvester when the grain moisture is below 14 percent	If the grains appear hard when pressed under teeth, then the crop is ready for harvest.	Grain quality will be better at optimum time of harvesting. There may be less damage due to pest under proper storage and germination will be better.	Doesn't use combine harvester if the moisture is more otherwise grains will be damaged and the grain quality will be affected fetching lower prices.
Storage	Moisture should be below 12 percent.	Storage should be at airy open space. Use pesticides in rainy season.	In rainy season, grains will absorb moisture and may be damaged by storage pests.	Don't store at high moisture condition, otherwise it may lose viability or storage pest damage may occur.