ADDRESSING SUSTAINABILITY ISSUES OF RICE-WHEAT CROPPING SYSTEM

Directorate of Extension Education
CCS Haryana Agricultural University
Hisar–125 004, India

Rajbir Garg, A. S. Dahiya, Sher Singh,
S. N. Singh, Ashok Yadav, A. K. Dhaka,
H. R. Malik, B. P. Rana, S. S. Dahiya,
A. K. Rathee and Kuldeep Kumar

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Rice and wheat crops.

Authors
Rajbir Garg, Sr. DES (Agronomy), CCSHAU Krishi Vigyan Kendra, Ujha (Panipat).
A. S. Dahiya, Sr. Co-ordinator, CCSHAU Krishi Vigyan Kendra, Ujha (Panipat).
Sher Singh, Research Associate, Department of Agronomy, CCSHAU, Hisar.
S. N. Singh, Sr. DES (Extension Education), CCSHAU Krishi Vigyan Kendra, Ujha (Panipat).
Ashok Yadav, Scientist (Weed Control), Department of Agronomy, CCSHAU, Hisar.
A. K. Dhaka, Research Associate, CCSHAU Krishi Vigyan Kendra, Ujha (Panipat).
H. R. Malik, Sr. DES (Soil Science), CCSHAU Krishi Vigyan Kendra, Ujha (Panipat).
B. P. Rana, Sr. DES (Plant Pathology), CCSHAU Krishi Vigyan Kendra, Ujha (Panipat).
S.S. Dahiya, Sr. DES (Agronomy), CCSHAU Krishi Vigyan Kendra, Jagdishpur (Sonipat).
A.K. Rathee, Sr. DES (Farm Management), CCSHAU Krishi Vigyan Kendra, Jagdishpur (Sonipat).
Kuldeep Kumar, Scientist, CCSHAU Krishi Vigyan Kendra, Jhajjar.

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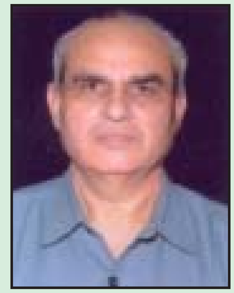


Vice-Chancellor
CCS Haryana Agricultural University, Hisar

FOREWORD

Rice-Wheat Cropping System (RWCS) is most critical to India's food security. In order to sustain the productivity of this cropping system, a number of reforms were introduced to conserve resources and to cut the cost of cultivation. In fact, depletion of natural resources as reported by the scientists of National Agricultural Research System (NARS) and International Agricultural Research System (IARS) lies at the root of arguments that favour the development of Resource Conservation Technologies (RCT) in RWCS.

Diversification is often considered as a crucial common thread to conserve natural resources in this cropping system. The system as a whole has come under attack because the share of natural resources that RWCS consumes is distinctly higher compared to other cropping systems. The Johl Committee has recommended a balanced approach to diversification. There is a general resistance to diversification because the profitability of rice and wheat generally stays ahead of the competitive crops. This can only be narrowed down by increasing the per hectare productivity of alternate crops through technological interventions.

While suggesting alternatives, wheat researchers need to keep in mind the viability and practicability of what works and what does not. Any research output is good if it attracts farmers and is bad if it gets ignored. A farmer considers profitability as the key component having strategic significance for taking decision. Efforts to diversify the RWCS in favour of crops other than rice and wheat seem not to have worked. The resistance of farmers to grow alternate crops makes this system a test case for the large scale changes that are needed for acceleration of RCTs. So, there remains an opportunity for large scale introduction of RCTs. The balancing effect of RCTs will allow RWCS to maintain the ecosystem integrity and economic viability.

Diversification through value addition in the form of an integrated farming system and through intercropping is more likely to be accepted by the farmers because the average returns on the investment can be more favourable than the alternate crops. The productivity at individual farm level has to grow faster so that unit labour cost is less and profits are more. The project on "DBT Rural Bio-resource Complex in Villages of Hisar and Sonipat Districts" is targeting the integrated farming system at village level. This bulletin seems to help extension agencies and farmers to introduce new options for sustainable farming.

(J. C. Katyal)

CONTENTS

INTRODUCTION

The rice-wheat cropping system (RWCS) may be age-old practice but its present worth was triggered by the development of high yielding varieties in both the crops. Green revolution since 1970s facilitated its expansion and is now estimated 24 million ha. This includes China with about 10 million ha and rest is in the Indo-Gangetic Plains (IGP) of India, Pakistan, Nepal and Bangladesh. In India, Punjab and Haryana are the core states where 95% of rice area is followed by wheat. The comparative higher productivity and stability of this system provided employment and income to rural masses and also ensured the food security for the country. Indeed the livelihood of million of farmers and workers is dependent on this very system. Despite the population explosion, South Asian countries are able to keep pace in food availability, reducing the incidence of poverty, hunger and starvation. But now this system is showing the sign of fatigue. The yield stagnation with declining factor productivity is all-apparent. Moreover, there has been enormous damage to natural resources. The declining soil fertility, depletion of ground water, rising problem of salinity and alkalinity, increasing problem of weeds, insect-pest and disease complex are very serious issues. This coupled with glut situation and falling global prices for both crops is a matter of great concern.

The state introduced public procurement and number of subsidy instruments during the green revolution phase to motivate the farmers for adoption of new technologies to increase productivity and production of food crops. It was a resounding success and food deficit India is now facing the problem of plenty. The continuation of all such incentives in the post-green revolution period is distorting the relative crop economics. The vested interests, parochial agenda and political calculations are impeding the process of reforms. The central and state governments are worried about subsidy burden.

There is question mark on the ecological and economic sustainability of this system. Diversification has become the focal issue in all policy initiatives but implementation part is ill defined. The diversification as the green revolution technologies has to demand driven with an accelerated pace and this is possible only by twisting the terms of trade between different crop commodities under pro-active role of government. The stakes and interests of farmers and other beneficiaries should be counter guaranteed during the early phase of diversification. Alternatively, it should be made sustainable by incorporating resource-conserving technologies. It is the plain clear that in the clash between resource conservation and monetary advantage it is the later which prevails.

This bulletin seeks to highlight all relevant issues in a holistic manner so as to save the breadbasket while maintaining the productive potential of natural resources. An attempt has also been made to present the insider view as no breakthrough is possible in the campaign for necessary corrections in the rice-wheat cropping system without the participation of farmers.

IMPORTANCE OF RICE-WHEAT CROPPING SYSTEM

- Food security is an integral part of national security. Arm twisting measures of USA during the war of 1965 and 1971 with Pakistan bear testimony to this fact. India could withstand the international pressure after Pokhran-II for that we are comfortable on food front. This is all because of rice-wheat cropping system (RWCS).
- To feed ever increasing population that is already above one billion we need to increase the food production. Any breakthrough in this regard is expected from rice and wheat. Any campaign of organic farming, resource conservation and environment management cannot ignore this fact.
- The creation of Haryana in 1966 coincided with the advent of green revolution and thereby the RWCS. The green revolution sweeping the state in its infancy proved to be a watershed which laid the foundation for phenomenon growth in the state.
- By augmenting the food supply through vertical growth, this system rather avoided the onslaught on forest land and other natural vegetation (Fig. 1).
- The incidence of poverty in core area of this system spreading in Punjab, Haryana and Western Uttar Pradesh is very low. The increase in rice and wheat supplies through green revolution era significantly brought down real prices to reducing poverty in India from 56% in 1973 to 26% at present.
- Food grain production of Haryana increased from 26 lac tonnes in 1966-67 to 132 lac tonnes at present. The contribution of rice and wheat in it was 50% in 1966-67, but now it is more than 90% (Table 1). The corresponding figures for the country as a whole in the year 1999-2000 and 2003-04 were 210 and 212 million tonnes, respectively. The contribution of rice and wheat towards total food grain production at national level was 79.2 and 75.0% in 1999-2000 and 2003-04, respectively. This happened because of area shift as well as productivity gains in both rice and wheat. However, it created one black hole that pulses were nearly eliminated from the cropping system in irrigated agro-ecosystem.
- The twin states of Haryana and Punjab contribute much of their produce to the national pool and that is major reason for their greater say in policy imperatives on agriculture at national level.

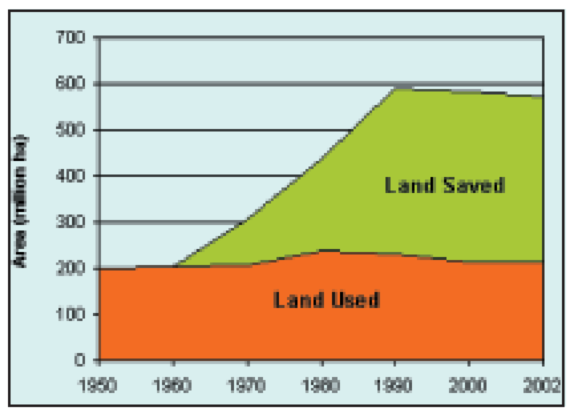


Fig. 1. Saving land with modern wheat varieties, global trend.
Source : FAO Statistical Database, 2003.
http://faostat.fao.org/faostat/collections?subset=agriculture

Table 1. Shift in cropping pattern and composition of food grain production in Haryana

Year	Total area (m ha)	% Share Rice	% Share Wheat	% Share Coarse cereals	% Share Pulses	Total production (m tonnes)	% Share Rice	% Share Wheat	% Share Coarse cereals	% Share Pulses
1966-67	3.52	5.4	21.1	40.8	32.7	2.59	8.6	40.9	28.8	2.2
1980-81	3.96	12.2	37.3	30.4	20.1	6.04	20.9	57.8	13.0	8.3
1990-91	4.08	16.2	45.4	20.2	18.2	9.56	19.2	67.3	7.8	5.7
1998-99	4.48	27.2	48.8	17.9	9.1	12.12	20.1	70.8	6.4	2.7
2004-05	4.23	24.3	55.2	6.2	4.1	13.11	23.1	69.1	6.7	1.1

APPARENT CONCERNS FROM RICE-WHEAT CROPPING SYSTEM

Currently there is growing concern in sustainability of rice-wheat cropping system (RWCS) as the growth rates of rice and wheat yields are either stagnant or declining. Punjab and Haryana regions (a major part of RWCS belt of India), which today serve as India's food basket, may become very food insecure in another 20 years (Swaminanthan, 2002). The importance of RWCS is a foregone conclusion but any prediction about its future shape needs cautious optimism. There is wide concern about the sustainability of this system. Some of the important issues are :

Depletion of Ground Water Resources

It is a serious issue to ponder with. Though ground water is a natural bounty with highest possible irrigation efficiency, whereas the development of surface water irrigation potential is a very costly affair entailing even the loss of productive land in networking of canals alongwith the associated problem of waterlogging, salinity, etc. But this gift of nature is over exploited in an unsustainable manner as evident from the following facts :

- The surface water availability of Haryana increased from 9.72 in 1971 to 14.33 lakh ha in 2004, whereas ground water availability increased from 5.74 to 15.22 lakh ha during the same reporting period (Fig. 2).
- The number of tubewells in the state of Haryana increased from 1.04 lacs in 1966-67 to 6.07 lacs in 2004 (Fig. 2).
- Apart from numerical rise, farmers are going for submersible tubewells with higher discharge, thus aggravating the problem of over draft.
- The stage of ground water development is around 109% for the state as a whole, whereas it ranges from 137% in Karnal to 179% in Kaithal (Table 2).
- The five key districts of RWCS (Karnal, Kurukshetra, Panipat, Kaithal and Fatehabad) are worst affected. There has been steep decline in water table over the years (Table 3).

Table 2. Groundwater resource of paddy districts in Haryana (2005)

District	Net annual ground water availability (ha m)	Existing gross ground water draft for all uses (ha m)	Domestic and industrial requirement for next 25 years (ha m)	Net ground water availability for future irrigation development	Stage of ground water development (%)
Fatehabad	38806	53140	369	-14461	137
Kaithal	56313	100652	3597	-45439	179
Karnal	87850	120479	1854	-33238	137
Kurukshetra	40439	66974	4167	-27924	166
Panipat	32942	51435	897	-18894	156
State Total	863177	945085	60000	-106555	109

Source : Central Ground Water Board, North-Western Region, Chandigarh (http://cgwbchd.nic.in).

Table 3. Excessive dependence on ground water – Impact on water levels

District	Water table depth (m)		
Kaithal	4 (1979)	10 (1995)	22 (2005)
Karnal	5-14 (1979)	8-18 (1995)	11-23 (2005)
Panipat	5 (1976)	13 (1995)	21 (2005)
Fatehabad	16 (1979)	22 (1995)	30 (2005)
Kurkushetra	14 (1987)	18 (1995)	25 (2005)

Figures in parentheses are the years of observation.
Source : Central Ground Water Board, North-Western Region, Chandigarh (http://cgwbchd.nic.in).

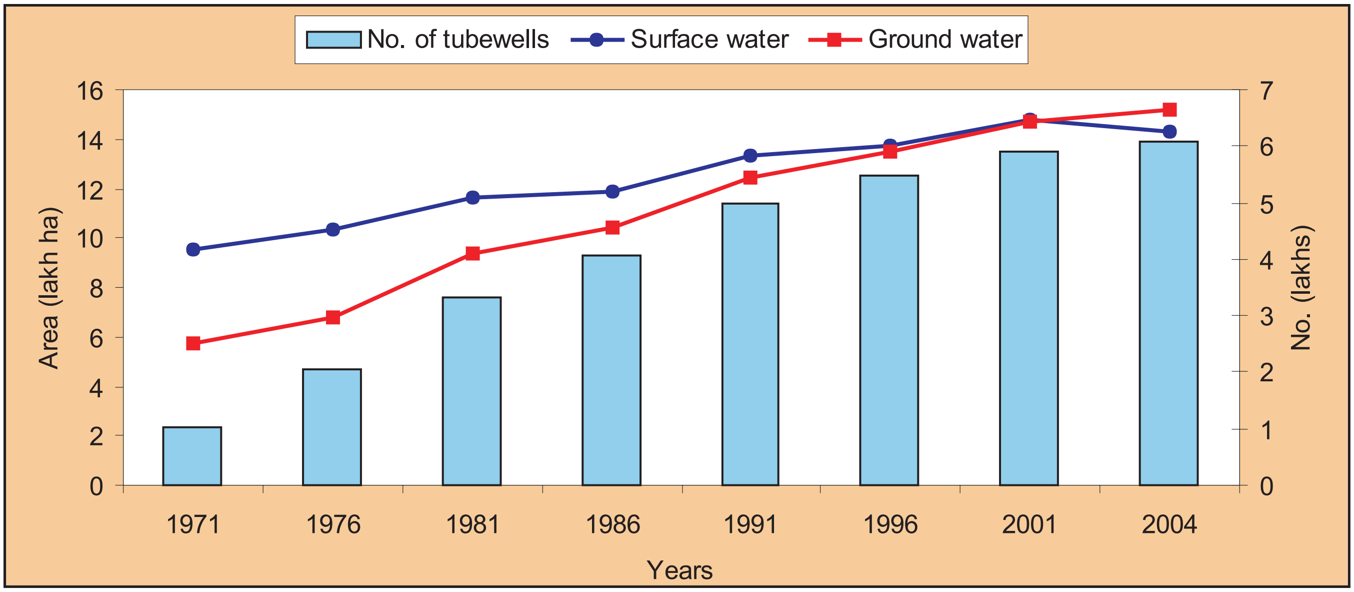


Fig. 2. Growth of tubewells and net area irrigated by surface and ground water in Haryana.
Source : Central Ground Water Board, North-Western Region, Chandigarh (http://cgwbchd.nic.in).

Decline in Soil Fertility

Increase in productivity means the simultaneous increase in nutrient mining and fertilizers requirement. Both trends are equally damaging as far as the quality of soil resources, environmental pollution and cost of production are concerned. Out of 16 plant nutrients, C, H and O being contributed by air and water, rest 13 are taken up from soil. Presently, farmers apply nitrogen, phosphorus and zinc only *i.e.* for other 10 nutrients we are ruthless on soil bank. The status of potash and various micronutrients is going down and may not be sufficient to meet the requirement of the crop (Tables 4 and 5). Their application as fertilizer will push the cost of production, thus eating in the already squeezed profit margin of the farmers.

Apart from nutrient status *per se*, the decline in organic fertility of the soil is rather more serious. The organic matter present in the soil being the food stock of soil micro-organisms indirectly mediates various chemical and biological reactions and also creates suitable physical environment. In the major rice-wheat regions of North-West India, soil carbon has decreased from 0.05 in 1960's to 0.02% in the late 1990's. Such a decline is prevalent throughout the RWCS in India. There is perceptible decrease in the efficiency of chemical fertilizers.

Table 4. Soil fertility status of Haryana

Nutrients	Percentage of soil samples		
	Low	Medium	High
		1980	
Organic carbon	80	18	2
Available P	25	40	35
Available K	—	18	82
		2003	
Organic carbon	92.0	7.5	0.5
Available P	70.6	27.5	1.9
Available K	7.8	42.2	50.0

Source : Antil *et al.* (2001).

Table 5. Status of micronutrients in soils of Haryana (2003)

Micronutrients	% samples deficient
Zn	54.0
Mn	4.4
Fe	21.0
Cu	2.6

Source : Gupta and Dahiya (2003).

Decline in Factor Productivity

This is grey area from farmers' point of view. While the yields are stagnating and even declining in certain cases, input use pattern reflects progressive increase in nutrient demand, more application of pesticides and also strain on water front. This implies that input use efficiency is decreasing with simultaneous increase in cost of production. The higher cost of production in any crop increases the risk probabilities. Any natural calamity may push the farmer to the corner and suicidal tendencies will come to the fore. The net income is declining and farmers are finding hard to maintain their living standards. In Haryana, the annual growth rate in total factor productivity has slowed down with time (Table 6).

Rising Problem of Insect-pest and Disease Complex

Both rice and wheat crops are grown under luxurious environment. The lush green crop with liberal use of nitrogenous fertilizers and constant moist condition becomes a paradise for insect-pest and disease complex (Fig. 3). Under the circumstances farmers tend to act on the advice of dealers, are adding complexity to the situation. This situation is further deteriorated by monoculture. Some of important issues are :

- Blast and stem borer used to the problem of tall statured basmati varieties but now the incidence is occurring in other varieties as well.
- Sheath blight considered to be minor disease restricted to border areas has become the major

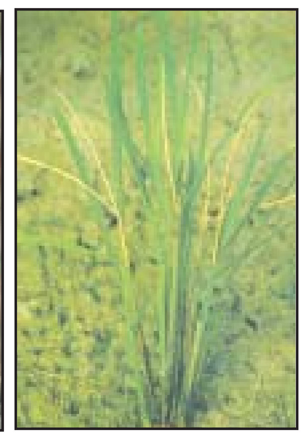
Table 6. Trends in indices of factor productivity (TFP) of RWCS in Punjab, Haryana and Uttar Pradesh states of India

State	TFP (%)			Annual growth rate (%)		
	1976[a]	1985	1992	1976-85	1985-92	1976-92
Punjab	75.8	97.9	103.1	3.2	0.8	1.9
Haryana	84.2	103.7	103.9	2.4	0.1 NS[b]	1.4
Uttar Pradesh	99.3	128.4	120.1	2.2	1.2 1.6	

[a]Average figures for the triennium ending the year given.
[b]Not significant.
Source : Kumar *et al*. (1998).

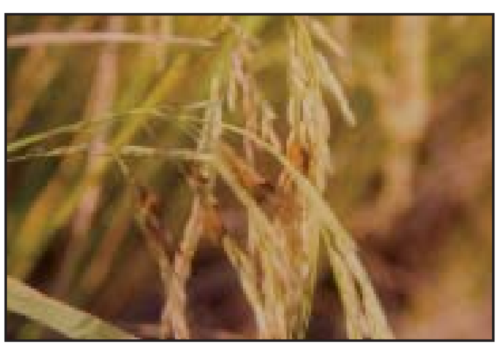
Sheath blight in rice

Neck blast in rice



Stem borer in rice – dead hearts

Stem borer in rice – white earheads



False smut in rice

Powdery mildew in wheat

Fig. 3. Emerging insect-pests and diseases in rice-wheat cropping system.

disease. **Kharif** 2005 can be considered as an epidemic year for this disease.

- False smut often considered to be a sign of bumper crop causes heavy losses now. The increasing area under hybrids will add to woes here.
- Aphid in wheat is likely to be a regular pest in the years to come. Use of pesticides near maturity may leave residues in the grain and straw, thus contaminating the food chain. This is more serious as wheat is our staple food.
- There is no effective management intervention for dreaded bacterial leaf blight in rice. Powdery mildew and rusts may be the yield-limiting factors in wheat.

Shift in Weed Flora

Severe infestation of weeds is one of the major factors for the decline in factor productivity of this cropping system. Various reports have reckoned that due to intensification of this cropping system, the weed flora has been simplified with the dominance of annual grasses. In high potential rice-wheat belt of the state, weed management has been associated with second generation problems. In the early 1990s, the resistance in *Phalaris minor* against isoproturon led to the record low production of wheat in the affected areas. It was kind of a vacuum where the establishment was neither mentally nor technically equipped to tackle the problem. Though the situation is under control now but problem of cross-resistance cannot be ruled out. Emerging weeds like *Sphenoclea zeylanica* in rice, *Rumex retroflexus* and *Malva parviflora* in wheat (Fig. 4) would require special attention. Alternative left is to adopt the Integrated Weed Management approach where monitoring of shifting weed flora alongwith other options including partial diversification may be the key components.

Glut Condition and State Procurement

The food deficit states of yester years are showing signs of progress on agricultural front easing the pressure on central pool and statutory buffer stocks. This has the fallout on market condition for wheat and rice in Punjab and Haryana. In rice crop, Haryana is rather comfortable because of proportionately large area under basmati rice which is procured by private millers and then exported, but Punjab always faces a problem. Both states have faced problem in wheat in previous years but conditions in 2005-06 have been different. The procurement agencies fell short of targets and government is resorting to bulk import of wheat to replenish the diminishing buffer stocks. This may be temporary phenomenon. With one or two good years on weather front, the situation may be back to square one. Ignoring the pace of demand and supply, both crops are procured at minimum support price. Though it is required to have a level playing field for the farmers already in distress, but nation has to pay a heavy price. This produce coming at the cost of huge natural resources and monetary inputs is allowed to rot or being exported at much

Sphenoclea zeylanica (Mirch butti) *Rumex retroflexus* (Jangli palak) *Malva parviflora* (Malva)

Fig. 4. Emerging weeds in rice-wheat cropping system.

lower price. Conversely, country has to import pulses and oilseeds involving the drain of precious foreign exchange. Inspite of heavy political stakes this situation cannot continue forever.

State Subsidies on Power, Fertilizer and Irrigation

These subsidies are riding high on the minds of planners :

- The electric power to tubewells (Fig. 5) is supplied at nominal flat rates. The power subsidy alone to rice crop is about Rs.10000 ha^{-1}. The rice crop period coincides with peak demand period in domestic sector which strains the limited power supply involving load shedding and frequent cuts. The industrial sector to loose heavily leading to unemployment and revenue loss to the state. Thus, invisible part of subsidy is also mind boggling to that power utilities may come forward to support voluntary diversification from rice through monetary incentives. A seminar on "Improving Power Availability – Voluntary Diversification from Paddy Cultivation to Other Crops" was held on 30 December, 2005 at CCS Haryana Agricultural Universoty, Hisar. The key recommendations of the seminar were :
    1. Long duration paddy varieties specially those requiring more than 145 days should be discouraged.
    2. There should be diversification within RWCS. Major savings can come by encouraging cultivation of Basmati rice. For encouraging Basmati rice, the Government should provide supportive prices. The subsidy component may be diverted to Basmati rice.
    3. Double cropping of rice must be discouraged. As far as possible summer rice is concerned, the state can think for banning summer rice in the long run.
    4. The adoption of site specific resource conservation technologies including zero tillage, bed planting, laser land levelling, lining of field channels, inter-cropping of sugarcane with alternative crops avoiding summer planting of sugarcane and encouraging autumn planting of sugarcane.
- The subsidy on urea and decontrolled phosphatic and potassic fertilizers during 2004-05 was Rs. 10737 and 5142 crores, respectively aggregating to total fertilizer subsidy of Rs.15879 crores. With increase in retention price and fertilizer consumption, this burden will be ever increasing. Rice and wheat grown under irrigated environment with high fertilizer doses are the major consumers of this subsidy.
- Creation of irrigation potential is capital intensive process and resource starved states will find it difficult to even manage the existing canal network (Fig. 5). This subsidy will also have a say in the future of this cropping system. Water productivity can be increased many-fold through extensive irrigation as against the artificial ponding in rice crop.

Fig. 5. Tubewells (ground water) and canal (surface water) – main source of irrigation in RWCS of Indo-Gangetic Plains of India.

WHY THE FARMERS ARE CRAZY FOR RICE-WHEAT CROPPING SYSTEM?

- Despite the ecological damage the farmers are still persisting with wheat and rice because of assured production and market. The support price is announced by the Commission for Agriculture Cost and Prices for all major crops but it is meaningless in the absence of state procurement. Practically, support price is just for rice and wheat and that is a big incentive for the farmers. Within rice also it is largely for high yielding varieties, whereas basmati growers equally face the price uncertainties.
- Both are principal food crops and definite production will always be needed. The government will never be in a position to pull out its hand all of a sudden. There is no such policy consistency in other crops.
- There exists all kind of infrastructural support for both the crops. This system is in vogue for last many years and backward and forward linkages were created in due course of time.

Fig. 6. Contrasting requirements of rice and wheat crops.

- The western part (Punjab, Haryana and Western Uttar Pradesh) of Rice-Wheat belt of Indo-Gangetic Plains, where wheat is the predominent crop, provides a favourable environment through assured irrigation for both rice and wheat crops (Fig. 6). The overall rice and wheat yields here are almost twice the yields obtained in the eastern states of Indo-Gangetic Plains. Cropping is highly mechanised and intense inputs are applied. The rice crop is invariably followed by wheat. About 95% of the area under rice in Punjab and Haryana is under rice-wheat cropping system (RWCS). There is reason for that. The rice crop requires peculiar anaerobic edaphic environment, which does affect the performance of succeeding **rabi** crop. Wheat is the kind of crop where potential yield can be realized even after rice though we have to overexert to optimize the growing environment, particularly the extra dose of nitrogenous fertilizers. Same is not true for other **rabi** crops. Pulses and oilseeds are bound to loose a yield portion after rice due to poor physico-chemical soil environment.
- The triple role of farmer as labour, manager and capitalist has undergone sea change. The contribution of family labour in the production process is negligible. Even the management in most of the cases is very casual. With the level of mechanisation and hired labour from Bihar, he is able to grow rice and wheat even under lazy atmosphere. Same may not be true in case of other crops.

HOW TO STABILIZE AND SUSTAIN THE RICE-WHEAT CROPPING SYSTEM?

There has been enormous damage to natural resources but things are inreversible limits. There are technologies which can undo the wrongs of previous years. Some of the important resource conserving technologies are described here.

Zero Tillage

Zero tillage as breakthrough in wheat cultivation is near equivalent to the development of high yielding varieties (HYV) in 1960s, though for contrasting reasons. The HYV in wheat were meant for increasing the productivity and ultimately led to the exploitative agriculture. Zero tillage is to reduce the cost of production and thereby to usher in conservative agriculture (Fig. 7). It saves energy, retains residues and improves the soil physico-biological environment with yields at par or higher than conventional tillage. The additional income accrued through this practice is about Rs.3000 ha^{-1}. Salient features with pros and cons between zero tillage and conventional tillage in wheat are given in box below :

Features and requirement	Zero tillage	Conventional tillage
1. Land preparation	Not required	More levelling and cost involved
2. Planting	Need to be done when moisture is relatively more or when farmer's field will come in working condition in a day or two	Tractor ploughing leads to cloudy field, if the field is not in perfect working condition. Reduced tillage some time not possible due to such situations
3. Seed requirement	Same	Same
4. Seedling emergence	1-2 days early, less emergence shock, even faster growth	Uneven seedling emergence, slow growth
5. Crust formation	No crust formation if rains occur just after sowing and germination is not affected. However, irrigation is not suggested immediately after sowing.	Crust formation takes place after rains and germination is hampered.
6. Density	Adjustable as per recommended seed rate	Adjustable as per recommended seed rate but uneven
7. Colour of seedling at emergence and after first irrigation	Dark green due to better placement and utilization of phosphate fertilizer. No yellowing of leaves after first irrigation.	Yellow due to uneven distribution of fertilizer. Yellowing of leaves after first irrigation
8. Irrigation schedule	Normal	Normal
9. Water management	Less water in first irrigation, more precise, pre-sowing irrigation can be avoided when rice is harvested in 4th week of October	More water in first irrigation, less precise, pre-sowing irrigation cannot be avoided in all situations
10. Water stagnation	Less	More
11. Weed management	Sometimes pre-seeding herbicides are needed. Post-emergence herbicides needed. *Phalaris* population is less in early sowings.	Pre-seeding herbicides not needed. Post-emergence herbicides needed. *Phalaris* population is more.
12. Fertilizer requirement	Normal	Normal
13. Ripening	Uniform	Uneven
14. Lodging	Less	More
15. Harvesting	Uniform maturity	Slower maturation due to staggered emergence
16. Yields	Yield advantage in timely sown wheat	No yield advantage
17. Success under salt affected soils	More	Less
18. Distinctive feature	Less labour, less cost of cultivation, 75% less diesel, no yield penalty and more eco-friendly	More labour, more cost of cultivation, more fuel consumption and less eco-friendly

Source : Malik *et al.* (2002).

Fig. 7. Zero-tillage in wheat.

Green Manuring

There is a fallow period of 45-50 days between harvest of wheat and transplanting of rice which is sufficient to raise a very good green manure crop. Though any leguminous crop can be used for green manuring but *Sesbania aculeata* is best fit (Fig. 8). It grows well even on marginal soils, could accumulate about 250 q ha^{-1} biomass in seven weeks. Its incorporation in the soil can contribute 60-80 kg N ha^{-1}. The carbon and nitrogen ratio is ideal for rapid decomposition and nitrogen availability is as fast as from urea. Green manuring alone is sufficient to meet all the nitrogen need of Basmati rice, whereas in other varieties it is possible to skip the basal dose. Even the phosphatic fertilizers meant for rice can be applied to *Sesbania* crop with added efficacy. The 2/3 of the recommended doses would suffice here. The role of green manuring in improving the soil biophysics and water management is well documented. In puddled fields it tends to avoid or delay the crack formation under water scarcity. This is the best possible mean of carbon sequestration.

Fig. 8. Green manuring in rice.

Crop Residue Management

Due to short turn-around period between two crops in RWCS, crop residue management is a serious problem. In the Indian sub-continent the major problem is the management of rice residue, as rice is harvested during the end of October to the end of November, where the optimum sowing period of wheat is mid November. As a contrast, there is a gap of two months between wheat harvest and rice planting and the wheat residue can be removed easily. However, wheat residue management becomes a problem if a third crop (rice/moongbean/cowpea/fodder) is taken during summer. Since it is very crucial to sustain the RWCS and in conservation tillage it is worth to retain 30% of the crop residues. Some of the empirical facts are as under :

- As the labour is scarce and costly, area under combine harvesting will increase thereby aggravating the problem of residue burning (Fig. 9).
- Residue burning particularly in wheat may create straw crisis for livestock. Otherwise also wheat straw fetching about Rs.5000 ha^{-1} can cover the cost of harvesting and threshing operations.
- With harvest index of about 50% in wheat, there is about 5 tonnes ha^{-1} stubbles. It is possible to recover half of it as straw through reaper following the combine harvesting. The rest half of the residues can be successfully managed and even we can raise a very good green manure crop within the residues (Fig. 10). But there are not sufficient reapers in the system to keep pace with combines.

Fig. 9. Combine harvesting and residue burning in wheat – common practices.

Fig. 10. Straw harvest through reaper after combine harvesting, followed by green manuring.

- Stubbles of basmati rice are used as dry fodder for livestock, and thus residues are put to economic use. In areas having high livestock to land ratio, harvesting and threshing operation of basmati rice is done in exchange of 'Pural'.
- Residues of HYV in rice are invariably burnt in both manual and combine harvesting. The fallow period after rice is not sufficient to permit its incorporation in soil. It can be returned back to soil only through composting. Vermi-composting is a worthwhile technology in this regard.
- Special implements for residue incorporation to facilitate rapid decomposition will help in residue management.

Integrated Pest Management (IPM)

Injudicious use of pesticides leads to the development of resistance, nearly eliminates the natural enemies leading to the resurgence of pests at regular intervals. Wheat is comparatively a safe crop as far as pest incidence is concerned, but rice is emerging as the main guzzler of pesticides, probably next to cotton. Some of the glaring facts in farmer level management are :

- The farmer does not have pest management strategy in place. They spray on routine basis at predetermined intervals, grossly ignoring the kind of pest and disease problem at the moment. There is always a fear psychosis of yield loss and even chances of crop failure. This psycho horizon prompts him to apply more of pesticides, to his perception he is somehow avoiding the pest risk. The tendency of blanket spray does not omen well.
- The pesticide dealers in connivance with pesticide companies are promoting the injudicious use of pesticides.

- The quality of pesticides is still an issue. Law enforcement agencies need to be more vigilant with a sense of commitment. The strengthening of legal framework with deterrent punishment is also required.
- None of the IPM module, except the pesticide part, has been adopted at the farmer field. IPM modules need to be user friendly. Labour oriented component will be less adopted, as the labour is scarce and costly. There requires more manpower in place to guide the farmers all during the crop season from sowing to harvesting alongwith pre-sowing and post-harvest interventions. Resistant varieties and biological control will define the agenda of IPM in next generation and it is here the role of biotechnology comes in.

Judicious Water Management

Water-use-efficiency in RWCS is generally low. Water management in RWCS can be optimised by appropriate soil management to reduce percolation, proper scheduling of irrigation, use of ground water and utilisation of rain water. Thus, proper use of water resource may enhance the water productivity. For that :

- There is a key link between water availability and crop phenology in the yield maximization pursuits. There is hardly any coordination between the canal command authorities, power utilities and extension agencies to define water release pattern and power availability coinciding with the critical crop stages.
- The theft of canal water is more serious than the theft of power and never there is adequate water at the tail.
- The continuous submergence of paddy fields is not the crop requirement (Fig. 11). Irrigation at hairline cracks may be one of the options but this cannot be adopted as long as the canal water supply is uncertain and power supply is erratic.
- The agro-techniques like bed planting, zero tillage, etc. could save much of precious water with related benefits of yield margins (Fig. 11).
- Land levelling is sure to increase the water use efficiency. Laser land levellers can play very crucial role in this regard (Fig. 11).
- Unmanned night irrigation often leads to the wastage of water. The water flooding the roadside and unwanted reirrigation in neighbouring fields is a common sight.

Continuous submergence is not a must in rice. | Bed planting in wheat | Laser land levelling

Fig. 11. Water saving technologies in rice-wheat cropping system.

Summer Cultivation of Rice and Double Cropping

This practice coming out of human greediness plays foul with natural resources and overall ecology. Overdraft of ground water, strain on power supply often leading to the collapse of the distribution system may be a threat to rice crop in the main season. The government has banned this practice but there is a need to enforce it alongwith educative efforts to wean farmers away from this practice. Addition of some economics through fodder crop or summer moong can definitely help in this matter.

Early Transplanting

In recent years, there is increasing tendency among the farmers to go for early transplanting commencing from first week of June. It is partly borne out from uncertain power supply and labour problem. Farmers often report about yield gain in early transplanting but it is directly linked to poor plant population. Under poor plant stand (18-19 plants m^{-2} as against the recommended 33 plants m^{-2}) farmers tend to force extra tillering through early transplanting and excessive use of nitrogenous fertilizers. This has repercussions on water management strategy. The rice crop period is divisible into three components :

- **Pre-monsoon period –** It is more taxing as evapotranspiration demand is very high. This period is undesirable and transplanting of rice before 25 June, unless it is required to optimise the sowing time for succeeding crop, is undesirable.
- **Monsoonal period –** This period of 60-70 days decides the fate of rice crop. Good monsoon with even distribution eases the pressure on power utilities and reduces the draft of ground water.
- **Post-monsoon period –** The critical crop period is over, thermal moderation and good canopy cover drastically reduce the water requirement. The early transplanting of rice leads to early harvest in first week of October. Residual moisture could not be used, as wheat sowing is to commence in the end of October, this rather puts the burden of pre-sowing irrigation.

Varietal Distribution

Varietal selection of the farmers is purely on economic considerations and varietal basket in comparison to other component technologies is most dynamic and farmers plan for the next year on the basis of yield and price in the current year (Table 7). In many pockets, susceptible varieties are dominating the varietal spread. For instance, PB 1 alone occupies more than half of total area under rice in district Panipat. Similarly, Pusa 44 is the fancy of farmers in Punjab.

The unfavourable price scenario with wild fluctuations is forcing the farmers to shift from basmati rice. The worst part is that it is being substituted by hybrids where the farmers try to achieve the yield target of 9-10 tonnes ha^{-1} by overexerting the resources, nutrient mining, etc. The basmati rice with no pre-monsoon period saves lot of water and green manure alone could meet the nutrient requirement. The state intervention here is crucially required to maintain the area under basmati rice.

Table 7. Type of rice varieties grown and their yields in RWCS districts of Haryana during 2003-04

Type of rice varieties	Farmers reporting	Paddy yield (t ha^{-1})
Superfine (dwarf rice)	46.5%	5.93
Basmati (evolved)	30.2%	4.45
Basmati (traditional)	23.3%	2.58
Mean	–	4.71

Source : Erenstein *et al.* (2006).

Excessive Use of Nitrogenous Fertilizers and that of Granular Insecticides

The use of nitrogenous fertilizers is above the recommended doses in both rice and wheat. The farmers are using upto 343 kg N ha^{-1} in rice-wheat cropping system. However, use of phosphorus and zinc is below the recommended dose in this system (Table 8). The problem is more serious in rice. The farmers use the granular insecticides (cartap hydrochloride and fipronil) in rice for phyto-hormonic effects. There appears a stiff competition among the farmers to have the darkest colour foliage, but it is his folly. The crop is predisposed to insect-pest and disease complex. The use of leaf colour chart (LCC) for nitrogen management in rice may be quite helpful (Fig. 12).

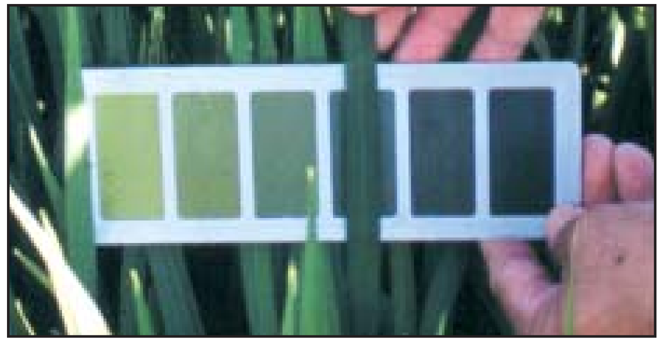


Fig. 12. Leaf colour chart based nitrogen management in rice crop.

Table 8. Nitrogen, phosphorus, potash and zinc application in rice and wheat crops in RWCS districts of Haryana during 2003-04

Chemical nutrient application rate	Rice				Wheat	Rice + wheat
	Superfine (dwarf rice)	Basmati (evolved)	Basmati (traditional)	Mean		
Nitrogen (kg N ha^{-1})	180:0	159.0	103.0	156.0	187.0	343.0
Phosphorus (kg P_2O_5 ha^{-1})	39.7	53.3	42.3	14.4	57.7	102.1
Potash (kg K_2O ha^{-1})	3.6	5.9	1.2	3.7	0.9	4.6
Zinc (kg $ZnSO_4$ ha^{-1})	6.7	7.3	7.3	7.0	0.2	7.2

Source : Erenstein *et al*. (2006).

DIVERSIFICATION ISSUES

Before pressing the panic button it is must to understand the entire gamut of diversification process. Half hearted approach may prove counterproductive and a costly failure. The experience of Punjab is with us. Some of the important issues are :

- In the diversification exercise farmers are not ready to compromise with their current returns. Any alternative system has to be equally paying on its own or has to be made through system of incentives and disincentives.
- Resource conservation is at the threshold of psyche of farmers but does not figure well in their crop management strategy. Resource conservation options in the absence of good economics may not appeal to the end users.
- Stability of production, price and ultimate returns in alternate crops i.e. pulses and oilseeds is inherently low. It may not be worthwhile to target one crop. It is imperative to work out the permutation and combination of crops where cropping system could possibly be stabilized.
- The extent and objective of diversification should be plain clear. The hot pursuit may land in food crisis and glut condition for alternate crops and particularly so in case of horticultural crops. Diversification never means the mere substitution of one crop by the other. It must lead to resource conservation with favourable economics in long run.
- Support price for alternate crops in consonance with state procurement or any other suitable mechanism of market intervention is a must, and also the support price should be such to ensure an edge in returns for a reasonably long period. It is for the planners to examine all the pros and cons before embarking on it.
- The subsidy component in rice-wheat cropping system is quite substantial and can there be a mechanism to cross this subsidy as bonus for alternate crops?

ALTERNATIVES OF RICE-WHEAT CROPPING SYSTEM

- In rice-wheat cropping system (RWCS) much of the problem relates to rice and it is the most remunerative crop in the **kharif** season with probably no alternative at present. It is a kind of compulsion for the farmers. The farmers are compulsive to grow rice. Apart from the core districts, the farmers of districts Jind, Rohtak, Sonepat and even Hisar are tempting to grow rice under sub-optimal conditions (Fig. 13) which is more damaging to the quality of natural resources.

- While retaining rice in **kharif** season, early varieties maturing in 95-105 days after transplanting will facilitate diversification (Fig. 14) within the RWCS as wheat alone is replaceable with two crops (mustard-summer moong, pea-potato, toria-sunflower, potato-sunflower, toria-potato, potato-onion, pea-cucurbits, raya cucurbits, etc.). The alternative three crop sequences with pulses and oilseeds in it will save the resources and may be equally profitable.

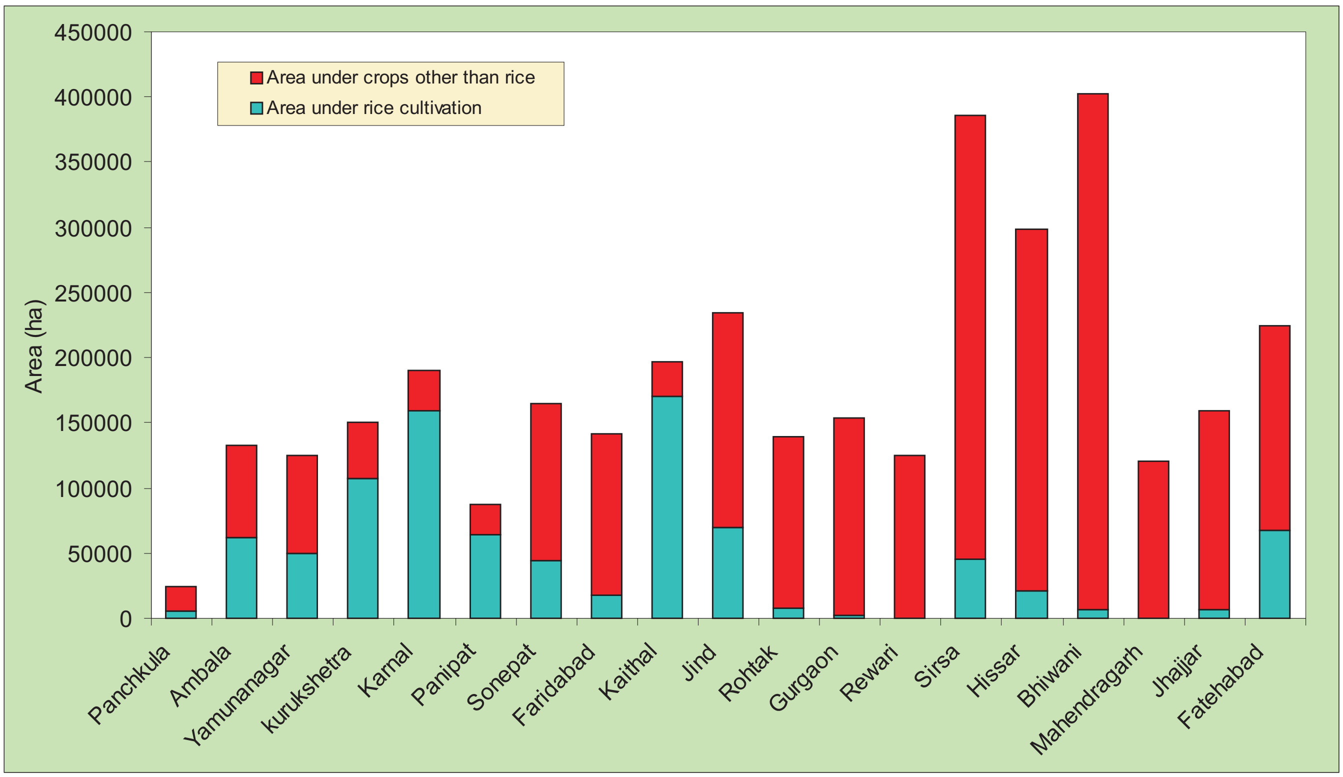


Fig. 13. District-wise area of rice and other crops in Haryana.

HKR 47 | Sharbati (Non-descript) | Pusa Sugandha 5

Fig. 14. Early maturing varieties of rice suitable for diversification.

- Sugarcane based cropping system is viable option. Sugarcane alone is a remunerative crop and also there is enough scope of value addition through intercropping (Fig. 15). The bed planting will play a major role in this endeavour. Just by optimizing the sowing time it is possible to increase the yield by 10-15%. There is chance for other innovative technologies like pit method of planting, nursery raising, multiple ratooning, etc.
- Fruit and vegetable crops may suit in urban hinterlands. These are perishable commodities and any glut here may ruin the farmers. Their horizontal expansion has to be a planned exercise with a back up of cold storages and food processing industries. The contract farming has a space here.
- Medicinal and aromatic plants are the emerging areas but basic research work is required to develop the package of practices and also to define the quality parameters. The market is uncertain. It is advisable for the farmers to move on slow pace and gradually expand the business on the basis of their own experience.

Sugarcane – Potato fb Cucumber

Sugarcane + Onion

Sugarcane + Wheat

Fig. 15. Intercropping in autumn planted sugarcane – way to diversification.

VEGETABLE BASED DIVERSIFICATION IN SONIPAT DISTRICT

The rice-wheat cropping system has been the fastest growing cropping system in North-eastern Haryana. Of late, concerns have been expressed over the continuance of this pre-dominant cropping system of the region, as such. The high potential areas where this system is being extensively practised are facing several kinds of environmental, economical and ecological problems. Other concerning issues (broadly at macro level) are shrinking resource base, changes in demand and consumption pattern, changing farming systems, declining public investments in agriculture and international developments such as liberalization of agricultural trade and W.T.O. agreements, etc. Owing to these concerns/issues this cropping system has now become the subject of debate among economists, agronomists and policy makers. The economists and policymakers have focused their strategies towards diversification through policy changes. On the contrary, scientists including agronomists have targeted diversification through value-addition and demand-driven technology generation.

In rice-wheat cropping system, farmers use the natural resources inefficiently and the profit margins as such are not as high as these have been in the past. The profit margins in this system have ranged from 6 to 13 per cent and that even is not uniform across the categories of farmers. The average profits of farmers of Sonipat district (and to that extent of Panipat district's also) can be increased by adoption of high value vegetable crops, exotic vegetables, spices, flowers and mushroom cultivation at an increased level. Different studies on diversification have also shown that at micro level a shift towards high value crops had benefited not only the farmer-grower but the poor also by directly raising agricultural productivity and generating additional employment. On consumption side too, as per NSSO data (and other studies too), the consumption of high value crops (specifically in this case it is vegetables, fruit crops and spice crops) is growing at a much faster rate (13.8, 10.2 and 8.1 per cent, respectively) as compared to cereals (7%) in Haryana too.

Sonipat is one of the most successful districts for vegetable farming as the steady increase in acreage under vegetable crops has shown its wider adoption by the farmers over years (Tables 9-11).

Table 9. Area under vegetable crops over years in Sonipat district

Year	Area (ha)
1980-1981	6464
1993-1994	7878
1999-2000	21118
2004-05	22754
2005-06	24773

Table 10. Area under different vegetable crops in Sonipat district (2005-06)

Crop	Area (ha)	Crop	Area (ha)
Cauliflower	3245	Carrot	2990
Cucurbits	2670	Radish	2550
Cabbage	2290	Peas	2145
Okra	1752	Tomato	1340
Potato	1060	Onion	1045
Brinjal	917	Chilli	369
Arbi	50	Leafy vegetables	1758
Others	1292		

Table 11. Area under spices, flowers, exotic vegetables and mushroom in Sonipat district (2005-06)

Crop	Area (ha)
Spices	469
Exotic vegetables	142
Flowers	1099
Mushroom	351010 (trays)

The economic indicators of profitability and employment generation of these high value vegetable crops, spices and mushroom *i.e.* B : C ratio (Benefit : cost ratio) and human days requirement (Table 12) for almost all of these crops/ enterprises indicate higher per rupee earning from the farmers investment (return on capital) in these high value crops/enterprises. This comparatively much higher profitability from these crops (vegetable, spices, mushroom) is the deciding factor towards diversification of area under vegetable crops, spice crops, flowers and mushroom in the district. The area under different vegetable crops touches 24773 ha in the year 2005-06 from a mere 6464 ha during 1980-81. Mushroom cultivation reaches this level from a modest start only in early eighties. So is the case with exotic vegetables and flower crops.

Table 12. B : C ratio and human days requirement of traditional crops vis-a-vis high value crops in Sonipat district

Crop	B : C ratio	Human days requirement/ha
Paddy	1.13	117
Wheat	1.18	102
Sugarcane (P)	1.10	177
Sugarcane (R)	1.38	160
Sugarcane + Raya	1.31	198
Onion	1.69	240
Okra	1.75	258
Cauliflower	1.87	215
Chillies	1.66	232
Cucurbits	1.34	210
Tomato	1.63	365
Mushroom	1.67	140 (per 100 q straw)

This example is important for policy makers because the return on capital is indeed the key to diversification. Since the return on capital is relatively high (more so because of availability of efficient markets), farmers have started accepting these high value crops.

The CCSHAU is currently implementing RBC Project on Bio-resource complex in two villages of Sonipat district, namely, Barota and Bayanpur. The project is focusing on providing technical inputs to enterprises or farming systems which are comparatively more profitable. It is also focusing on that part of farming system where the possibility of risk of bad loan is minimum. The profits from the enterprises that have been taken up in these villages are high in spite of the more or less equal cost of cultivation as in other areas but for the cost of selling, distribution and transportation which is less here in comparison to other districts. After deducting such costs the profit margins are likely to be more in these villages from these enterprises.

After conducting bench mark surveys and assessing the needs of the farmers, the preliminary data alongwith the vision upto the end of the project have been given in Table 13. These projections have been arrived at keeping in view the market needs, technical and economical feasibility of the crops/ enterprises concerned.

Table 13. Base line data and vision for RBC villages

Crop/ enterprise	Base year		Vision at the end of Project	
	Barota	Bayanpur	Barota	Bayanpur
Paddy	600	720	500	600
Wheat	700	800	600	700
Vegetable crops	220	50	480	400
Flowers	110	2	300	100
Spices	10	5	50	50
Mushroom	5	15	20	30
Honey bee (Units)	1	–	1	5

In future, the wages may go up and prices may fall because of W.T.O. agreements. In order to be more competitive the productivity has to grow even faster than wages/labour costs. Therefore, the productivity gains have to be matched by reduction in the cost of production. The focus ought to be on improving the total factor productivity (the efficiency with which capital and labour are used in farming) through reduction in cost of cultivation and improvement in productivity simultaneously. In future, the profits and capital spending must boom hand in hand. The approach for farming system should also include the realities of marketing, distribution and storage. Because of increasing pace of urbanization in Sonipat and Panipat districts gains in the returns on investment can be more through diversification not only within crops but also within enterprises (more specifically towards aforesaid high value vegetable crops and or mushroom, etc.). Profit margin for the farmers can rise further if the cost of production is also reduced in each component of the farming system through intervention of cost reduction technologies.

DIVERSIFICATION THROUGH FARMING SYSTEM

Rapid economic and income growth, urbanization and globanization are leading to a dramatic shift in Asian diets away from staples towards livestock and dairy products, vegetables and fruits, and fats and oils. The diversification of diets away from traditional dominance of rice with rising incomes is expected. The urbanization which is happening at a much faster rate around Panipat district the changes in food demand are likely to increase consumption of wheat and wheat based products, increased consumption of protein and energy dense diets, rising popularity of vegetables and fruits and increased consumption of milk. In Haryana, the population of buffalo is 6 million against the cultivated area of 3.6 million ha. The diversification in favour of subsidiary occupations including dairying, mushroom, honeybee, processed food, vegetables and fruits is more likely compared to diversification in favour of pulses or oilseeds. In Haryana, approximately 1.7 million farmers are holding 3.6 million ha land. The small holders' production system that exists in Panipat also faces increasing pressure to commercialized and diversified in terms of farming system because the existing cropping system including the best scenario of rice-wheat cropping system (RWCS) is facing the signs of fatigue with low factor productivity. We can see a gradual but definite movement from mono culture system to a diversitied market-oriented production system elaborated in Fig. 16.

The flexibility of farmers to respond to changing relative prices and relative profitability in their crop choice decision-making will depend on the type of farming system based on the option given in Fig. 16.

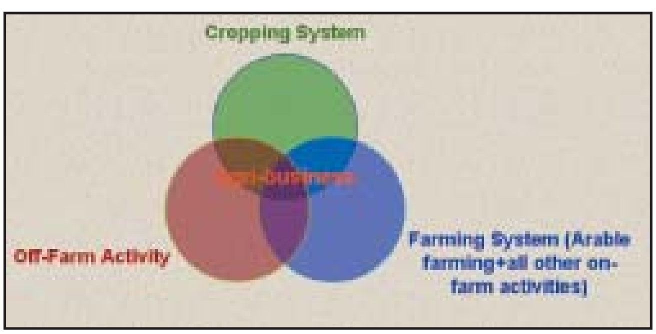


Fig. 16. Rural Bio-resource Complex.

Alongwith the diversification in the existing cropping systems and varietal basket there of ample opportunities do exist for diversification through farming system. The net returns from various crop enterprises are falling in the backdrop of yield plateaus, unfavourable terms of trade and diminishing factor productivity. The needs and aspirations of farming lot are increasing. The urge for materialistic pleasure is no less than urbanites. He is finding hard to maintain the existing living standards. It is ironical that farmers are tending to borrow for social and consumption expenditure, of course, in the guise of crop loans and other term loans. This is creating the problem of indebtedness in the rural society and may prove fatal for the cooperative banking in the years to come. The vicious cycle of low productivity and misery was dented by the green revolution in 1970s, but the farming community is reverting back to an era of deficit economy. The reverse gear syndrome can be arrested by sufficient monetary advantage through integration of cropping systems with other allied enterprises, thus, providing gainful employment and incentives for new generation peasantry. Therefore, farming system approach is the need of the hour and be integral part of structural adjustments and transformation in the agricultural sector (RWC-CIMMYT, 2003).

Diversified farming system is not a euphemism for traditional subsistence system as a coping mechanism for risk aversion. In the market driven global phenomenon, it is rather a strategy to optimize the resource use pattern including the human resource, generate additional output, income and employment, alleviate poverty and export orientation to usher in peace and prosperity.

In the farming system approach there is in-built synergy for many of our concerns :

Dairying

- Dairying at commercial level means the more area under fodder based cropping systems, that need driven shift in crops will automatically diversify the RWCS.
- More return of FYM to the soil will improve the soil health, even vermicomposting can be integrated with commercial dairies.

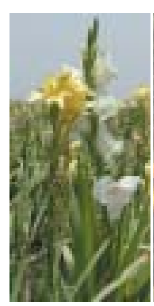
- Most of our cattle population is thriving on crop residues and weeds. Wheat straw is the buffer feed stock and even 'Pural' of basmati rice is used. The crop residues may become an economic entity and this will curb the residue burning. There is chance for mechanical and manual weeding in the pursuit of integrated weed management.
- Crops of dual nature providing green and/or dry fodder alongwith economic product (sugarcane, bajra, maize, etc.) may become more important in the crop sequences, again facilitating the diversification of RWCS.

Mushroom Cultivation

- The mushroom is grown on compost prepared from lignin rich crop residues. This will add value to the perceived waste and liability. Inspite of manual harvesting, rice stubbles are placed in heaps and then burnt adding much carbon load in the atmosphere. Same stubbles can be converted into nutritious mushroom, generating income and employment in the process.

Poultry

- It is the best user of coarse cereals grown in marginal areas and dry pockets. The poultry industry already growing in double digits may provide market push to bajra and maize. The poulty manure will be other benefit.



Floriculture, Horticultural Crops, Forestry, Medicinal and Aromatic Plants

- These high value crops may facilitate a paradigm shift towards organic and specialized peri-urban farming. The shift towards high value crops also benefits the poor by directly generating employment and raising agricultural productivity. The producer as well as the hired labour receives the direct income benefits.

Fisheries

- In marginal areas characterized by shallow water tables and brackish ground water, fishery can be good option. Instead of seasonal ponding in rice-ecosystem, it may be more profitable to have a fishery pond. This will also arrest the damage to natural resources arising from RWCS in below optimum environment.

Apiculture

- Apiculture is another enterprise which can be profitably integrated with the cultivation of oilseed crops like mustard and sunflower. Eucalyptus under agro-forestry system, berseem under fodder based cropping sequences and many other horticultural crops can also be potential source of pollen and nectar. The apiculture not only generates income through sale of honey, wax and colonies, but is quite helpful in cross pollinated crops. Apiculture if successfully integrated with alternative systems having mustard and sunflower in the rotation will create better economic environment for their adoption by the farmers.

This synergy is well taken but the documentation of **'ready-to-adopt'** farming system of available farm resources, capital and risk perceptions is quite challenging. There is apparent need for multidisciplinary research to evolve location specific models and particularly for small and marginal farmers. Any farming system model for Haryana needs to have **'Dairying'** at the centre, closely circled by crops, whereas other options at the periphery. India is the largest producer of milk with Haryana at the forefront. There has been five-fold increases in milk production since 1966-67, whereas per capita availability is 643 g, as against 232 g for the country as a whole (Table 14). Out of 52.21 lac tonnes milk production in Haryana, share of cow, buffalo and goat is 10.23, 40.89 and 1.09 lac tonnes, respectively.

Table 14. Milk production status of Haryana

Year	Milk production (Lac tonnes)	Per capita milk availability (g day^{-1})
1966-67	10.89	352
1980-81	21.87 (316)	484 (128)
1990-91	34.19 (539)	571 (176)
2000-01	48.45 (806)	637 (220)
2003-04	52.21 (910)	643 (232)

The figures in parentheses are for the country as a whole.

There is still the huge potential to reduce the cost while augmenting the output on the other. The germplasm upgradation at work may usher in era of highly profitable dairies and crop enterprises may even take the back seat for the average farmer. Even the professionals may enter in big way around urban areas and surging in a partnership with farmers of hinterlands. This can also be a boom for absentee farmers. Henceforth, a sound and practical understanding of scope, circumstances and limitations in the contours of diversified farming system is required by invoking the bottom/up approach. There is relevance of farmers' participatory mode in this pursuit as well. This would also require support in designing suitable policy framework for evolution of required institutional arrangements, adequate infrastructure, market intelligence, export orientation and long-term goals and objectives.

Research efforts and extension strategy for technologies, which clash with traditional wisdom involving paradigm shift, need a relook. In such technologies :

- Research output is location specific and may not be generalized.
- Research output has to be correlated with socio-psycho perceptions, resource base, policy issues and kind of acceptability.
- All findings have to be defined in the overall agro-ecological matrix to capture the impact on soil biophysics, environmental management and even on the market behaviour of crop commodities in question.
- The objective is long and lasting returns alongwith viable current returns. The conventional cost analysis may not hold good, as it does not monetise the resource conservation.
- The long-term permanent sites have to be integral part of such studies.

The conventional research at research station may not suffice here and it has to be complemented and supplemented with 'On-farm Testing' or 'Farmer Participatory Research'. Such approach has in-built extension mechanism as the research plot simultaneously acts as demonstration plot. Data generated in real farming situation appreciating all constraints have more worth when these come to push the technologies on larger area. Moreover, these reduce the time lag in the generation and transfer of technology. The beauty of this approach is that generation, refinement and transfer of a technology is a simultaneous process, in contrast to succession approach in traditional set-up. Some of the 'On-farm studies' carried out have been discussed herewith :

1. Green Manuring for Integrated Nutrient Management (INM) in Basmati Rice

This study was carried out at farmers' field in district Panipat of Haryana state during the years 2001-02 to 2005-06 using two treatments :

T_1–Farmers' practice (No green manuring, 80 kg N+58 kg P_2O_5+25 kg $ZnSO_4$ ha^{-1}. All of phosphorus and zinc sulfate were applied within one week of transplanting of rice, whereas nitrogen was applied in two equal splits at 20-25 and 40-45 days after transplanting).

T_2–Recommended INM practice (Green manuring, 20 kg P_2O_5+25 kg $ZnSO_4$ ha^{-1}. All of the phosphorus was applied to green manure crop at sowing time and zinc sulfate applied within one week of transplanting of rice).

The key finding are :

- Green manuring alone is sufficient to meet all the nitrogen need of basmati rice. It could save 80 kg N and 38 kg P_2O_5 ha^{-1} in comparison to farmers' practice.
- The average yield increase under green manuring was 7.5%. The increase was comparatively more in drought years indicating its role in water management as well (Fig. 17).
- The cost involved in green manuring based INM practice was more than the farmers' practice implying that cost of green manuring was more than it could save in terms of fertilizers. In some years current returns may be negative by few hundred rupees but such small amount is negotiable for long and lasting returns (Table 15).
- No significant effect of green manuring was observed on the yield of wheat crop raised with uniform agronomic package (150 kg N+60 kg P_2O_5 ha^{-1}) in both the treatments.
- Farmers tend to analyse green manuring as practice to save some urea and too cumbersome to adopt. Such perception grossly ignored the conservative nature of this practice. The tendency of early transplanting of rice also acted for cross-purpose. As a result the adoption level is very low.

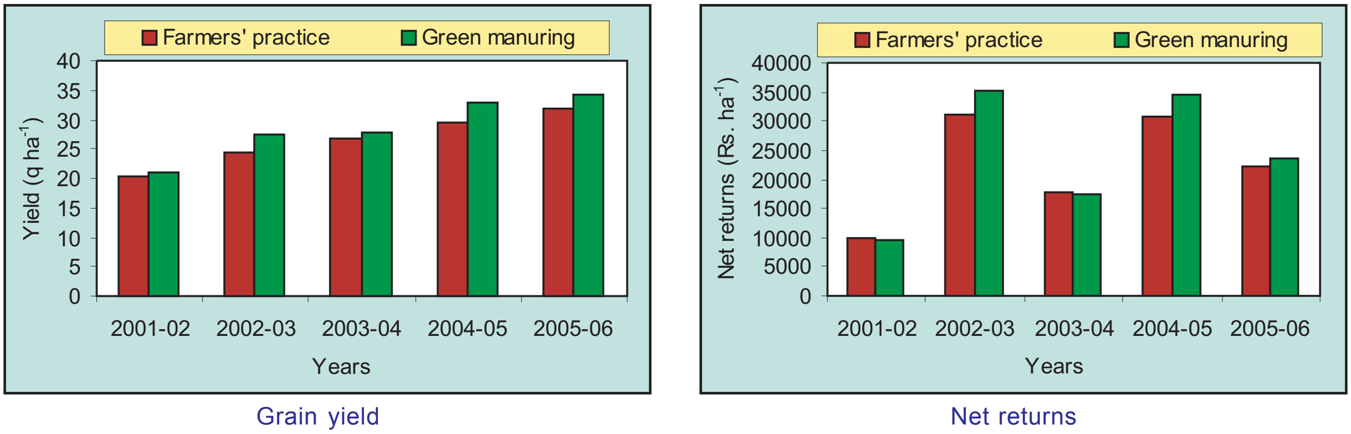


Fig. 17. Comparative yield and net returns of Basmati rice under farmers' practice and green manuring.

Table 15. Effect of green manuring on yield and economics of Basmati rice

Year	Treatments	Yield (q ha^{-1})	% increase in yield	Cost (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})
2001-02	FP	20.5 (48.2)	–	16593	26600	10007
	GM	21.1 (48.6)	2.9	17693	27320	9619
2002-03	FP	24.5 (47.8)	–	17265	48315	31050
	GM	27.5 (48.5)	8.1	18548	53925	35377
2003-04	FP	26.9 (44.6)	–	15896	33704	17808
	GM	27.7 (45.1)	4.1	17121	34632	17511
2004-05	FP	29.6 (45.8)	–	16812	47492	30680
	GM	32.9 (46.1)	11.2	18012	52508	34496
2005-06	FP	31.9 (44.3)	–	19690	42000	22310
	GM	34.9 (44.9)	7.5	21313	45000	23687
Average	FP	26.7 (46.1)	–	17251	39622	22371
	GM	28.8 (46.6)	7.9	18537	42677	24138

FP–Farmers' practice, GM–Green manuring. The figures in parentheses indicate the yield of wheat (q ha^{-1}).

Sale price for rice	2001-02	2002-03	2003-04	2004-05	2005-06
Grain (Rs. q^{-1})	1200	1870	1160	1520	1250
Straw (Rs. ha^{-1})	2000	2500	2500	2500	2125
Rice variety	HBC 19	HBC 19	HBC 19	HBC 19	CSR 30

- The availability of the seed of *Sesbania* is the major constraint. For instance, 1750 tonnes of seed is required to cover the 70,000 ha of rice crop under green manuring in the district Panipat. The seed availability is just a fraction of it. The seed production programme of *Sesbania* has to be taken up as in case of other crops. The marginal areas and Panchayat lands may be tapped for this purpose.
- Good impact of this study was observed. The on-farm testing alongwith educative efforts did help to bring the mental twist. The area under green manuring in the operational area increased from meager 17 to 362 ha in a span of five years. The adoption rate for district as a whole is also increasing (Fig. 18).

2. Zero Tillage in Rice-Wheat Cropping System

- Slight yield advantage in zero tillage over the conventional practice was observed during all the years of study. The direct seeding through zero tillage reduced the production cost by Rs.1998 ha^{-1}. The net additional returns as accrued through yield advantage and reduced cost came out to be Rs.3067 ha^{-1}. The population of *Phalaris minor* was consistently lower in zero tillage than conventional tillage (Table 16).

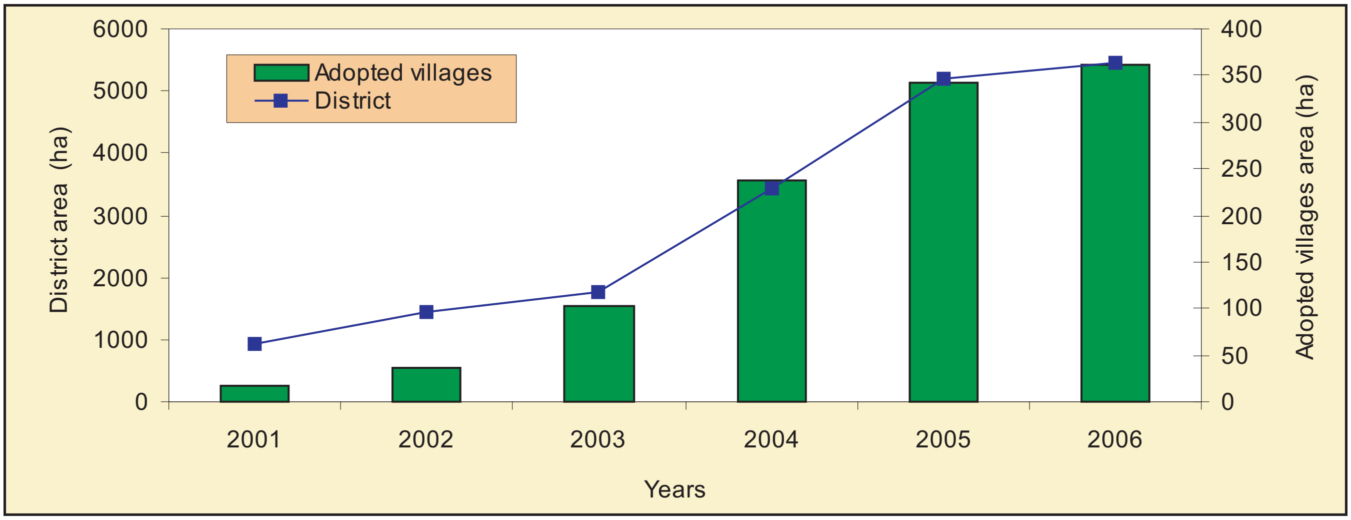


Fig. 18. Impact- Progressive increase in area (ha) under green manuring over time.

- There was no adverse effect of zero tillage in wheat on performance of succeeding crop of Basmati rice (var. HBC 19) in terms of yield and pest incidence. The basmati rice was specifically selected for this study as it is more prone to insect-pest and disease complex. The incidence of leaf folder, stem borer and neck blast was at par with conventional tillage (Table 17).
- As the technology clashed with the traditional mind set of the farmers, demonstration of the worth of technology on their own farm or the

Table 16. Effect of zero tillage on the emergence pattern of *Phalaris minor*, yield and returns of wheat

Year	Treatment	No. of trials	Weed population m^{-2}				Yield (q ha^{-1})	Cost cut (Rs. ha^{-1})	Net additional returns (Rs. ha^{-1})
			Phalaris minor		*Rumex*				
			21 DAS	35 DAS	21 DAS	35 DAS			
2000-01	Conventional tillage	20	308	9	963	77	48.5	–	–
	Zero tillage		169	24	872	144	50.9	1711	3175
2001-02	Conventional tillage	20	219	12	817	106	48.9	–	–
	Zero tillage		93	37	624	168	51.0	1970	3272
2002-03	Conventional tillage	20	283	11	1016	115	48.8	–	–
	Zero tillage		176	29	778	158	49.5	2313	2754
Average	Conventional tillage	60	270	11	932	99	48.7	–	–
	Zero tillage		146	30	758	157	50.5	1998	3067

DAS – Days after sowing.
Sale price of wheat grain–Rs. 610 q^{-1} in 2000-01, Rs. 620 q^{-1} in 2001-02, Rs. 630 q^{-1} in 2002-03.

Table 17. Effect of zero tillage on the pest incidence and yield of succeeding Basmati rice (var. HBC 19) crop

Year	Treatment	No. of trials	Leaf folder (%)	Stem borer (%)	Neck blast (%)	Yield (q ha^{-1})
2000-01	Conventional tillage	20	4.4	2.8	12.3	24.8
	Zero tillage		5.1	2.5	12.2	24.4
2001-02	Conventional tillage	20	7.3	2.4	11.2	25.4
	Zero tillage		6.4	2.8	11.8	25.9
2002-03	Conventional tillage	20	4.8	3.2	9.5	28.8
	Zero tillage		3.9	3.4	9.8	29.5
Average	Conventional tillage	60	5.5	2.8	11.0	26.3
	Zero tillage		5.1	2.9	11.3	26.6

nearby one brought the much-needed mental twist. The area under zero tillage in the selected villages increased from meager 12 ha in 2000-01 to 337 ha in 2005-06. The corresponding figures for the district as a whole were 740 ha in 2000-01 and 4325 ha in 2005-06 (Fig 19). The gains from zero-tillage technology at national level are shown in Table 18.

- Apart from monetary gains, resource-conserving nature of zero tillage is quite explicit. It saves planting time, fuel and water, improves efficiency of applied fertilizer nutrients, reduces wear and tear of tractor, promotes residue management and also reduces air pollution. The opinions of some farmers of Panipat district about the zero tillage technology in wheat are given in Annexure-I.
- There is almost negligible difference in the soil bulk density between zero tillage and conventional tillage in respective profiles (0-5, 5-10 and 10-20 cm); however, it increased with the corresponding increase in the depth of soil profile (Fig. 20). Thus, there is soft surface with more moisture retention under zero tillage. Temperature moderation with slightly more temperature in the month of February and less in the first week of April under zero tillage compared to conventional tillage (Fig. 21) has been found in the root zone of soil. This thermodynamism is helpful to wheat crop due to warming effect in February (avoids frost injury) and through cooling effect in the end of March or start of April to avoid from grain shrivelling and forced maturity (Yadav *et al.*, 2002).
- Under the conditions where yield tends to stagnate or decline, cost reduction is only alternative to increase the benefit. Zero tillage fits well in the scheme and needs a big boost through positive policy instruments.

Table 18. Area covered, saving in fuel and total net saving due to zero-tillage in wheat in India

Year	Area (ha)	Net gain (Million Rs.) @ Rs. 2600 ha^{-1}	Fuel saving (Million litres) @ 50 l ha^{-1}
2001-02	100000	260	5.0
2002-03	220000	572	11.0
2003-04	750000	1954	37.5
2004-05	1270000	3302	63.5
Total	2340000	6088	117.0

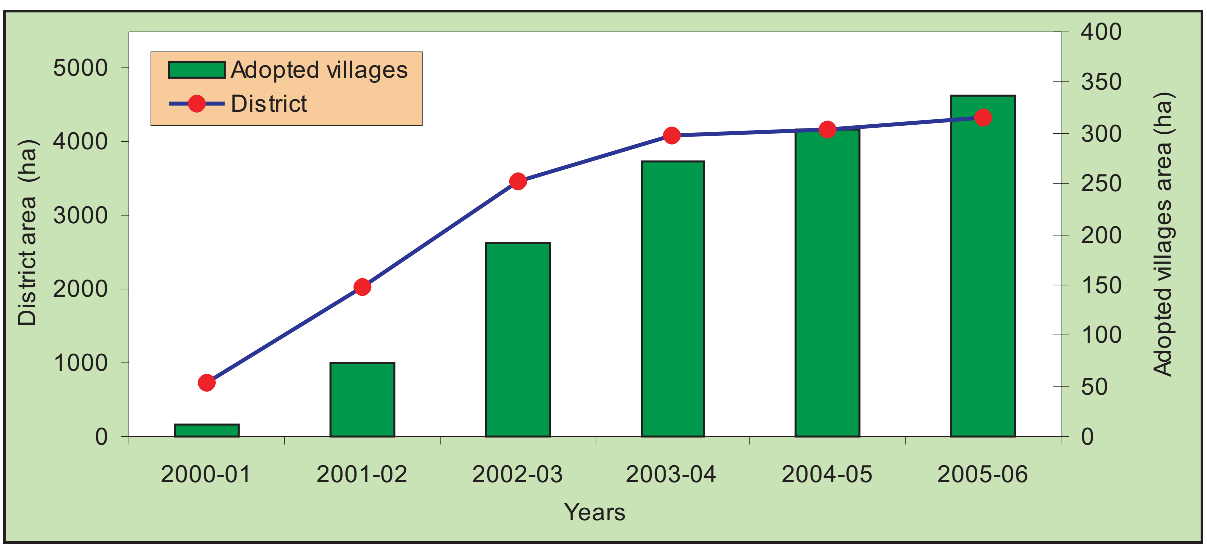


Fig. 19. Impact – Progressive increase in area (ha) under zero tillage over time.

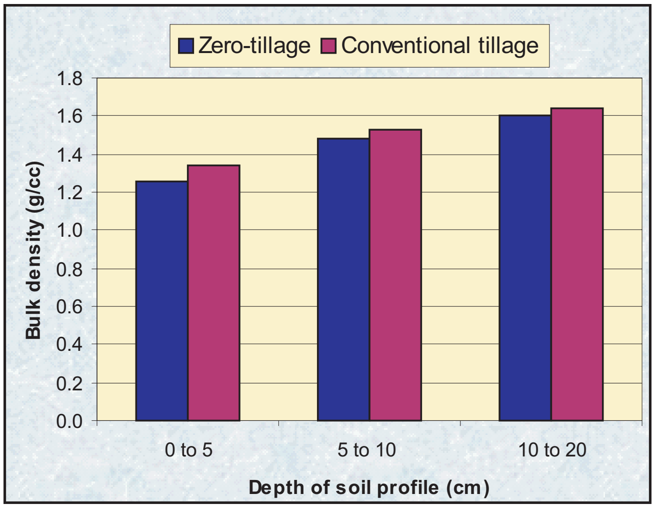


Fig. 20. Bulk density of soil as affected by tillage systems in wheat grown after rice.
Source : Yadav *et al*. (2002).

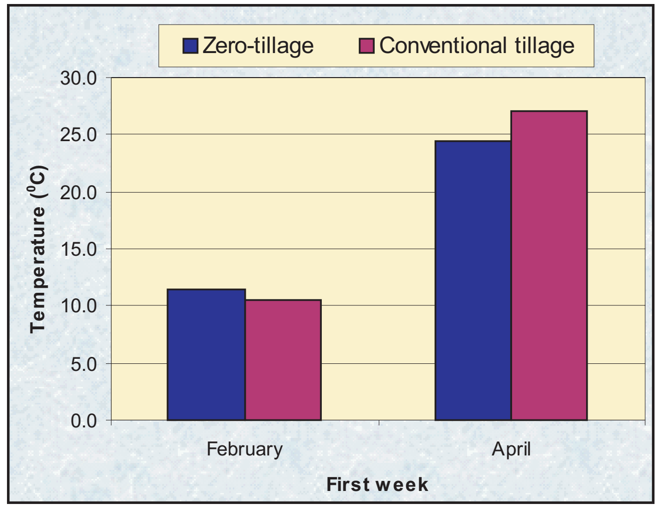


Fig. 21. Soil temperature moderation in wheat under zero tillage.
Source : Yadav *et al*. (2002).

3. Diversification Possibilities of RWCS

This study was conducted during 2002-03 to 2004-05 in district Panipat of Haryana to explore the possibilities of diversification in the existing RWCS using five treatments :

T_1–Rice (var. HBC 19)–wheat (var. PBW 343)

T_2–Rice (var. PB 1)–wheat (var. PBW 343)

T_3–Rice (var. PB 1)–gram (var. HC 1)

T_4–Rice (var. HKR 47)–mustard (var. Laxmi)–summer moong (var. Muskan)

T_5–Rice (var. Sharbati)–mustard (var. Laxmi)–summer mung (Muskan).

The alternative sequences in T_3, T_4 and T_5 were compared with two prevailing systems in T_1 and T_2 occupying around 25 and 50% of total area under rice in the district, respectively. The key findings are :

System Productivity and Economic Returns

- Among the different varieties of rice, highest grain yield was recorded in HKR 47. With quality addition there was decrease in the yield of Basmati rice but a corresponding increase in selling price was observed (Table 19). The lowest yield but highest price was obtained in HBC 19 (Traditional scented Basmati rice).
- The yield of wheat sown in the first week of November after rice (var. PB 1) in T_2 was about 3 q ha^{-1} more than that sown in third week of November after rice (var. HBC 19) in T_1 indicating that sowing time is very crucial for this crop (Table 19).
- The system productivity as evaluated in terms of wheat equivalent yield was comparatively higher in rice-mustard-summer moong sequence in T_4 and T_5. Thus, the productivity of the total system increased with increase in cropping intensity due to better utilization of time and space (Table 20).
- Corresponding to equivalent yield, the net returns in rice-mustard-summer moong sequence were also higher with a decisive margin of around Rs. 8000 to 12000 ha^{-1} over the rice-wheat sequence (Table 20).
- The cost-benefit ratio above 2 in either case reflects the potential productivity and profit margin in rice-wheat and rice based alternative cropping systems (Table 20). The cost-benefit ratio above two is quite safe to replace wheat with two crops in alternative systems.
- The one of the lowest wheat equivalent yields alongwith comparatively less net returns and poor stability indicated that rice-gram sequence might not be a viable option in the diversification pursuits (Table 20).

Table 19. Yield, stability, duration and sale price of different crops in various rice based cropping systems (Mean data of three years)

Crop	Variety	Yield ($q\ ha^{-1}$)	Stability index	Duration (Days)	Sale price (Rs. q^{-1})		
					2002-03	2003-04	2004-05
Rice, scented Basmati	HBC 19	28.2	0.83	126*	1870	1210	1520
Rice, semi-dwarf Basmati type	PB 1	46.7	0.80	117*	1150	920	1050
Rice, high yielding fine type	HKR 47	66.4	0.85	103*	610	620	590
Rice, high yielding super fine type	Sharbati	52.1	0.85	94*	690	740	800
Wheat[1], Late sown	PBW 343	44.9	0.84	149	630	630	640
Wheat[2], Timely sown	PBW 343	47.8	0.85	160	630	630	640
Mustard	Laxmi	16.8	0.69	147	1825	1650	1500
Gram	HC 1	15.7	0.57	155	1870	1530	1520
Summer Moong	Muskan	9.2	0.73	72	1520	1700	1950

*Days after transplanting.
[1]Wheat after rice var. HBC 19, Date of sowing – third week on November.
[2]Wheat after rice var. PB 1, Date of sowing – first week on November.

Table 20. Economics and relative efficiency of different cropping systems

Treatment	Wheat equ. yield ($q\ ha^{-1}$)	Gross returns (Rs. ha^{-1})	Cost (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	Cost - benefit ratio	Stability index	LUE (%)	PE (kg ha^{-1} day^{-1})
T_1– Rice (HBC 19)–wheat	113.5	78524	35330	43194	2.12	0.71	75.3	41.3
T_2– Rice (PB 1)–wheat	121.8	83374	36432	46942	2.29	0.78	75.9	44.0
T_3– Rice (PB 1)–gram	115.2	75365	29915	45450	2.52	0.66	74.5	42.7
T_4– Rice (HKR 47)–mustard –summer mung	132.1	85331	31015	54316	2.75	0.88	88.2	41.0
T_5– Rice (Sharbati)–mustard –summer mung	128.0	85134	30094	55040	2.83	0.87	85.7	40.9

LUE–Land use efficiency, PE–Production efficiency.

- This study suggests that straight out substitution of wheat and rice by any other crop may not be possible but increase in cropping intensity may provide the answer.
- There is no production problem in scented Basmati rice (var. HBC 19) but the price instability (Table 19) is a major issue which is forcing the farmers to go for other varieties including the hybrids. This is a very negative development as Basmati rice requires less of water and nutrients.

Stability Index

- Stability index of wheat and rice was better than mustard, gram and summer moong. This is universally acknowledged fact that pulses and oilseeds exhibit more yield variations due to their greater sensitivity to weather fluctuations (Table 19).
- Among the different varieties of rice lowest stability index was recorded in PB 1 (0.80). This variety is more prone to insect-pest and disease complex and its cultivation is considered as risky even by the farmers but the prospects of much higher returns still motivate them to go for it (Table 19).
- The gram was found as least stable crop.
- The stability index of individual crop may be less but their integration in suitable crop sequences may improve the stability of the system as a whole. Further, yield instabilities

may be countered by price variations as bad years on production front are usually associated with price spurt and vice-versa. It was, therefore, the stability index in rice-mustard-summer moong that was even better than T_1 and T_2. The lowest stability index (0.66) further negates rice-gram as an alternative (Table 20).

Land Use Efficiency (LUE) and Production Efficiency (PE)

- The low LUE in rice-wheat and rice-gram sequence (Table 20) indicates that these sequences were inferior in land use, as the land remained fallow for longer period after the harvest of **rabi** crops. Hence, there is scope of intensification and it may be worthwhile to raise green manure crop/summer mung after the harvest of wheat and gram, respectively. Such intensification may address the issue of sustainability in tandem with diversification efforts as the prevailing systems are still to stay on significant area (Table 19).
- Reverse trend was observed for production efficiency. It is widely accepted fact that increase in LUE with increase in cropping intensity is most likely to decrease the PE as the catch crop may not be able to utilize the fallow period with an efficiency at par with the principal crops in the sequence (Fig. 22). However, PE should be read with other economic indicators (Table 20).

Moong (Muskan)

Mustard (Laxmi)

Wheat (PBW 343)

Fig. 22. Combined productivity of mustard and summer moong in comparison to wheat holds the key to diversification.

Conclusions

- This study established the conceptual framework for diversification of rice-wheat cropping system through increase in cropping intensity by reducing the rice crop period (95-105 DAT), then replacing wheat by two crops. This conceptual framework could be used elsewhere to devise location specific sustainable alternative sequences.
- Breeding efforts in rice and alternative crops should be oriented to develop varieties for synergy in a system to have the maximum output on sustained basis.
- The reduction in rice crop period means the huge saving of water which is of paramount importance in the diversification objectives.
- The government intervention and necessary support are crucial to shake the pessimism of the farmers for the ultimate and wider adoption of alternative sequences. The support price cover has to be extended to alternative crops with necessary infrastructure support and favourable public policies.
- There is increasing trend towards short duration varieties of rice crop with a shift from wheat to vegetables, mustard and sugarcane. Much will depend on the government initiatives.

ANNEXURE-I

Farmers' opinion about zero tillage wheat in district Panipat (Haryana)

रणबीर सिंह सुपुत्र श्री ओमप्रकाश
गाँव गवालडा, पानीपत

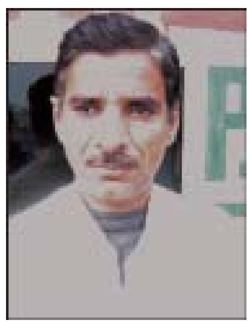
पांच दिन पहले बिजाई हो जाती है। किराया भी कम लगता है। जीरो टिलेज में खर्च कम आता है। फसल की बिजाई 10-14 दिन पहले हो जाती है। 25-26 लीटर डीजल कम लगता है। पानी की खपत भी कम है। खेत भरने में कम समय लगता है और पानी भी जल्दी सोख लेती है। गेहूँ पीली नहीं पड़ती। फसल गिरती भी कम है। बलुरी कम आती है। कम खर्च करने पर भी अच्छी पैदावार होती है। डाकर जमीन के लिए तो यह टैक्नोलोजी बहुत कामयाब है।

Ranbir Singh S/o Sh. Om Parkash
Village Gawalra, Panipat

Cost of cultivation is significantly reduced in zero tillage technique and sowing is advanced by 10-14 days, 25-26 litre diesel is saved. It takes less time to irrigate the fields so there is saving of irrigation water. Soil absorbs water easily so there is less damage due to heavy rains and lodging is also reduced. Infestation of *Phalaris minor* is also less. Overall there is higher production with less cost. The technology is particularly beneficial in heavy soils.

चांद सुपुत्र श्री स्वरूप सिंह
गाँव मांडी, पानीपत

इस तकनीक के बारे में मुझे सन् 1999 में के.वी.के, उझा से जानकारी मिली। पहली बार के.वी.के. वालों ने ही अपनी मशीन से बिजाई करवाई। बिना जुताई से गेहूँ बीजना एक आश्चर्य वाली बात थी सारा गांव इसे देखने आ रहा था सब कह रहे थे कि गेहूँ नहीं होगी पहले ऐसा ही लग रहा था पर जब जमवार हुआ और फसल बढ़ी तो सब देखते रह गये। इस विधि के कई फायदे हैं। किराया कम देना पड़ता है। इससे 1000 रु0 प्रति एकड़ की बचत होती है। समय पर बिजाई हो जाती है और फसल गिरती भी नहीं है। इसकी पैदावार 2-3 क्विंटल ज्यादा आती है। मैं इस तकनीक से पूरी तरह से सन्तुष्ट हूं।



Chand S/o Sh. Swaroop Singh
Village Mandi, Panipat

I came to know about zero tillage technology in 1999 from KVK, Ujha, Panipat. They provided me the machine at that time. Really it was amazing to sow wheat by this method, whole of the village was at my field. Initially everybody was in suspicion about germination, but the crop turned out to be a good one. There are many advantages of this technique. Saving of Rs. 1000 per acre is there, sowing is done timely, lodging problem is less, etc. Yield of crop is also higher by about 2-3 q per acre. I am very much satisfied with this technology.

बिजेन्द्र सुपुत्र श्री वेदपाल
गाँव चमराडा, पानीपत

जीरो टिलेज के बहुत फायदे हैं। डाकर जमीन में तो बहुत ही फायदा है। समय की बचत होती है। खर्च भी कम होता है। किराया 1000 रु0 कम देना पड़ता है। फसल गिरती भी नहीं है। नरम जमीन के कम फायदे हैं।

Bijender S/o Sh. Vedpal
Village Chamrada, Panipat

There are many benefits of zero tillage. This is particularly very beneficial in heavy soil. There is time saving and cost is also low. Rs. 1000 less are to be paid as hiring charges. There is no lodging of crop. There are less benefits in light soils.

राजेन्द्र सिंह सुपुत्र श्री भीम सिंह
गाँव बलाना, पानीपत

इस मशीन के बारे में सन् 2001 में कुरुक्षेत्र में एक रिश्तेदार के खेत पर देखा। अच्छी तकनीक है। इसमें हम 10 किलोग्राम कम बीज डालते हैं और खाद भी कम डालते हैं। खाद जड़ों में पड़ने के कारण जमवार व फुटाव भी अच्छा होता है। फसल गिरती भी नहीं है। कनकी भी कम आती है। पैदावार भी 1-2 क्विंटल बढ़ी है। मैं इस पद्धति से खुश हूँ।

Rajender Singh S/o Sh. Bhim Singh
Village Balana, Panipat

I saw this machine in 2001 in Kurukshetra at relative's farm. This is a good technique. We use 10 kg less seed and apply less fertilizers. Due to placement of fertilizer in cost zone, there is good tillering and there is no lodging. The population of Phalaris is also lower and 1-2 q increase in yield is there. I am happy with this technology.

नरेन्द्र सिंह सुपुत्र श्री ओम सिंह
गाँव चमराडा, पानीपत

जीरो टिलेज में किसान को सबसे बड़ा फायदा डीजल की बचत, समय की बचत, ट्रैक्टर की घिसाई कम होती है। इसमें 700-800 रु0 प्रति एकड़ बिजाई के समय बच जाते हैं। फसल गिरती भी नहीं है। इसकी बिजाई नमी में करनी चाहिए। डाकर जमीन के लिए बहुत उपयोगी है।

Narender Singh S/o Sh. Om Singh
Village Chamrada, Panipat

Benefits of zero tillage to the farmer are diesel and time saving. Less wear and tear of tractor. It saves Rs. 700-800 per acre at the time of sowing. There is no lodging of crop also. Sowing should be done in moist soil. This is very useful technique for heavy soil.

सतपाल सुपुत्र श्री औमप्रकाश
गाँव मांडी, पानीपत

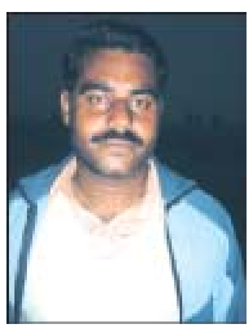
इस विधि से फसल की बुवाई अगेती व कम खर्च में हो जाती है। बीज भी कम लगता है समय भी बचता है। तेल भी कम लगता है। पैदावार छिड़के वाली गेहूँ के मुकाबले 1-2 क्विंटल ज्यादा आती है। मैं जीरो टिलेज की बिजाई से बेहद खुश हूँ।

Satpal S/o Sh. Om Parkash
Village Mandi, Panipat

By this technique sowing of crop can be done early with less cost, seed requirement is less and yield is 1-2 q higher as compared to broadcasting method. I am very happy to use this technology.

राजबीर सुपुत्र श्री जिले सिंह
गाँव दिवाना, पानीपत

जब पंजाब के किसान ने मुझे जीरो टिलेज के बारे में बताया तो मुझे उस पर विश्वास नहीं हुआ लेकिन जब 2000 में मैंने इस विधि से कनक की बुवाई की। इसमें बीज भी कम लगता है और गेहूँ की बिजाई में देरी नहीं हुई। गेहूँ अच्छा जमता है। फसल पहली सिंचाई के बाद पीली नहीं पड़ती। जब फसल बड़ी होने के बाद तेज हवा से गिरती नहीं है। पैदावार तो परम्परागत विधि के बराबर होती है परन्तु खर्चा कम होता है इसमें प्रति एकड़ 800-1000 रु0 की बचत है।



Rajbir S/o Sh. Jiley Singh
Village Diwana, Panipat

I did not believe when a Punjabi farmer told me about zero tillage but when I carried out sowing of wheat in 2000. It used less seed rate and saved time. Good grain. No yellowing of the crop after 1st irrigation. No lodging of standing crop by winds. Yield is same as that carried out by conventional means but saving is upto Rs.800-1000 per acre.

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2. Major Weeds of Rice-Wheat Cropping System
3. ***धान–गेहूँ फसल–चक्र में समन्वित पोषक तत्व प्रबन्धन : वर्मीतकनीक***
4. ***फसलों में खरपतवार नियंत्रण***
5. ***भूँईफोड़/मरगोजा (आरोबेंकी इजिप्टियाका पर्स.) की तिलहनी तोरिया में ग्रस्तता एवं प्रबंध हेतु विकल्प***
6. Broomrape (*Orobanche aegyptiaca* Pers.) Infestation in Oilseed Rapes and Management Options
7. Long-term Response of Zero-Tillage – Soil Fungi, Nematodes & Diseases of Rice-Wheat System
8. IPM Issues in Zero-Tillage System in Rice-Wheat Cropping Sequence
9. Zero Tillage – The Voice of Farmers
10. ***कृषि में विविधीकरण – खुम्बी उत्पादन का सफल प्रयास***
11. Animal Production and Health : Frequently Asked Questions
12. Project Workshop Proceedings on Accelerating the Adoption of Resource Conservation Technologies in Rice-Wheat Systems of the Indo-Gangetic Plains, June 1-2, 2005
13. ***आंवला उत्पादन एवं परिरक्षण***

OUR PRIORITIES

1. Diversification within rice-wheat cropping system (Basmati rice-wheat)

2. Diversification through farming system

3. Accelerate zero-tillage in wheat

4. Introduce summer mungbean/ green manuring between wheat and rice

5. Residue management

6. Bed planting – autumn sugarcane with intercrops

7. Laser land levelling

8. Rice-mustard-summer moongbean cropping system