

Challenges for barley production in India

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Barley cultivation in India is confined to the northern plains and preferred in dry areas with problematic soils due to its ability to thrive well under such situations. Once considered as poor man's crop now it is turning as commercial crop in India with the increasing use in malting and brewing. These requirements are demanding barley cultivation in optimally managed conditions, which will also bring new challenges for production and protection technologies in addition to the genetic improvement.

BARLEY (*Hordeum vulgare*) is an important coarse cereal crop of India, being grown in *rabi* (winter) season in Northern and North Eastern plains. Since long it has been considered, as poor man's crop because of its low input requirement and better adaptability to harsh environments, like drought, salinity and alkalinity and marginal lands. Area under the crop is concentrated in the states of Rajasthan, UP, MP, Punjab, Haryana, and Bihar in plains and Himachal Pradesh, Uttarakhand and Jammu & Kashmir in the hills. Barley occupies nearly 0.78 m ha area producing nearly 1.54 million tonnes grain, with a per hectare productivity of 19.74 q. Despite productivity gains through research efforts on varietal development and production technology, area under barley has consistently reduced in the country over nearly last 45 years of cultivation, which has seen a lot of revolutions during the period (Table 1). However, during past 15 years the area under barley has almost stabilized with minor annual fluctuations depending upon the price and industrial demand.

The decline in area under barley can be broadly categorized in two phases. In first (the green revolution) phase development of semi-dwarf wheat varieties with high yield potential made the farmers prefer wheat to barley. Since there was no such breakthrough in barley yield potential, the shift happened at an amazing speed. In the second (post green revolution) phase, the barley area again decreased significantly

because of development of irrigation network, popularization /demand of more remunerative oilseed crops like mustard for rainfed conditions and less demand for industrial utilization of barley. These factors confined barley to marginal, problematic soils as a rainfed crop, further adding to the decrease in the production of barley.

The recent increase in industrial demand of barley as raw material

DWRUB 52, the first malt variety developed under private - public partnership



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resulted in hike in market prices and created a situation of short supply. In fact presently only about 20-25% of the total barley production is used in the manufacture of malt and malt extract, which is further utilized for brewing, distillation, baby foods, cocoa-malt drinks and medicinal syrups. Rest of the production is utilized as cattle feed, cereal food and in preparation of local beverages in the tribal areas. The presently available six-row barley for malting industries possesses higher husk and less carbohydrate in endosperm that results in poor malting quality. It is mainly because of the non-cultivation of available malt type varieties and also because of poor management of the crop with irrigation and fertilizer. The continuous decline in barley area and production as well as reduced preference of farmers to grow barley under better management had triggered a shortage for good quality grain for malting in mid nineties. The Government of India has issued license to several new breweries, which created a demand for international quality malt as raw material for the breweries looking for the collaboration/competition with multinational companies.

In the recent years it has been observed that because of severe drought in the drier parts of northern plains, there is an acute shortage of green forage in the months of November to January. The common forage crops, berseem (*Trifolium* spp), oats (*Avena sativa*) and sugarcane require frequent irrigation, and can't be grown under water scarcity condition. The dual purpose barley can be a better option as green forage as well as grain crop in dry areas. In the era of climate change, where shortage of water and rise in temperature are becoming limitations, barley cultivation can provide a viable alternative to farmers.

Barley usage

Barley grain is used as feed for

animals, malt for industrial uses and human food. Barley straw is used as animal feed in many developing countries including India. Barley straw is also used for animal bedding and as cover material for hut roofs. Barley is also used for green forage and either directly fed to the animal or used for silage. It also has immense potential as quality cereal especially for nutritional and medicinal point of view. Malt is the second largest use of barley and malting barley is grown as a cash crop in a number of developed and developing countries including India. The utilization of barley for malting and brewing industry has picked up recently with an increase of consumption of beer and other malt based products in many countries including India. In India, presently about 20-25 % of the total barley production is used for malt and malt extract, which is further utilized for brewing, distillation, baby foods, cocoa-malt drinks and medicinal syrups. In developed countries barley is considered as a functional food and used in many bakery products and recipes. In India, its utilization as food crop (mainly hull less type) is restricted to the tribal areas of hills and plains. The barley products like "Sattu" (in summers because of its cooling effects on human body) and missi roti (for its better nutritional quality) have been traditionally used in India.

Research efforts for barley improvement in India

The research on barley improvement dates back to 1920's and 1930's in India, when by pure line selections a number of improved barley varieties like 'C 251', 'T 4', 'T 5' etc. were developed. Though these varieties were not aimed for malting, but because of their good grain type, were also utilized for malting. Amongst these, 'C 251' was exported to England for industrial utilization. The all India coordinated barley

improvement programme (AICBIP), involving Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs) centers was initiated to take up research on development of varieties for rainfed and irrigated cultivation under low fertility conditions of marginal soils in 1965-66. Presently the barley improvement programme under the All India Coordinated Wheat and Barley Improvement Project (AICW&BIP) involving seven funded and four voluntary centers located in major barley growing states, is in operation to address all major aspects. Each centre also has its regional mandate depending upon the agro-climatic conditions as well as the prevalent diseases/pest situation in addition to the national/zonal requirements. During early nineties, after the merger of AICBIP with AICWIP at DWR, the research and development efforts on barley as low input crop were strengthened and incorporation of resistance to prevalent diseases and pests in the zones was made mandatory. The Barley Network redefined its research priorities for barley improvement in view of the changing scenario during last decade and updated its objectives to address the needs of malt, feed and forage types barleys in the country. Keeping in view the changed scenario on barley the Barley Network Programme updated its objectives to address the needs of malt as well as feed barley in country as follows-

- Development of high-yielding varieties with superior malting qualities.
- Development of cultivars for restrictive environments, i.e. rainfed, saline/sodic soils, brackish water and diara lands.
- Development of varieties for feed and dual-purpose barley.
- Incorporation of resistance to various biotic stresses like, rusts, foliar blights, aphids and cereal cyst nematode.

Table 1. Trends in the area and production of barley in India

| Year | Area ('000 ha) | Production ('000 tonnes) | Productivity (kg/ha) |
|---------|----------------|--------------------------|----------------------|
| 1966-67 | 3375 | 3504 | 1038 |
| 1975-76 | 2802 | 3192 | 1139 |
| 1985-86 | 1369 | 1962 | 1433 |
| 1995-96 | 823 | 1510 | 1834 |
| 2005-06 | 629 | 1220 | 1938 |
| 2008-09 | 780 | 1540 | 1974 |

- Development of suitable crop protection and production technologies.

A number of varieties suiting to different cultural and agro-climatic conditions have been developed. In addition varieties for specific conditions like cold tolerance in Northern Hills and cyst nematode resistance for sick soils of Rajasthan and Haryana were also made available to the farmers. Systematic research efforts resulted in gradual improvement in productivity of the varieties. The genetic gain in yield potential under different production conditions in different zones is quite evident through new varieties. In addition to grain yield the barley breeders have successfully incorporated resistance to major biotic and abiotic stresses in the barley genotypes. The input management for the crops to get the economically sustainable production has become the biggest challenge in the present situation even for the crops like wheat. In case of barley the input requirement is just half (in terms of the nitrogen and water) and even with this kind of the inputs it has expressed very high yield potentials under the Frontline Demonstrations (FLDs) undertaken by the barley network centers in recent years.

Barley improvement for feed and food purposes

Majority of barley produced in India is utilized for cattle and poultry feed. The Barley Network centers

Table 2. Barley varieties released recently for feed purpose

| Cultural Practices | Variety | Year | Area of adaptation | Developed by | |
|--------------------------|---------------------|-----------|--------------------|---------------------|------------------|
| Irrigated | 'RD 2552' | 1999 | NWPZ, NEPZ | ARS, Durgapura | |
| | 'PL751' | 2006 | Central zone | PAU Ludhiana | |
| | 'BH 902' | 2010 | NWPZ | CCS HAU, Hisar | |
| | 'NB-2' ('NDB- 940') | 1999 | Uttar Pradesh | NDUA&T, Faizabad | |
| | 'BH 393' | 2001 | Haryana | HAU, Hisar | |
| | 'RD2592' | 2003 | Rajasthan | ARS, Durgapura | |
| | 'Jawahar Barley 1' | 2009 | Madhya Pradesh | COA, JNKV, Rewa | |
| | Rainfed (Plains) | 'K 560' | 1997 | NEPZ | CSAUA&T, Kanpur |
| | | 'K 603' | 2000 | NEPZ | CSAUA&T, Kanpur |
| | | 'RD 2624' | 2003 | NWPZ | ARS, Durgapura |
| 'RD 2660' | | 2006 | NWPZ | ARS, Durgapura | |
| 'Getanjali' ('K1149') | | 1997 | Uttar Pradesh | CSAUA&T, Kanpur | |
| 'PL 419' | | 1995 | Punjab | PAU, Ludhiana | |
| 'JB 58' | | 2005 | Madhya Pradesh | ARS, Rewa | |
| Rainfed (Northern Hills) | | 'HBL 276' | 1999 | Northern Hills Zone | HPKV, Bajaura |
| | | 'BHS 352' | 2003 | Northern Hills | IARI, RS, Shimla |
| | | 'BHS 380' | 2010 | Northern Hills Zone | IARI, RS, Shimla |
| | 'VLB 56' | 2005 | Uttarakhand | VPKAS, Almora | |
| | 'VLB 85' | 2008 | Uttarakhand | VPKAS, Almora | |
| | 'PRB 502' | 2009 | Uttarakhand | GBPUA&T, Pantnagar | |

Table 3. Barley varieties released for malting and brewing purposes

| Variety | Year | Production Condition | Area of Adaptation | Developed at |
|------------|------|----------------------|--------------------|---------------------|
| 'Alfa 93' | 1994 | Irrigated (TS) | NWPZ | DWR Karnal |
| 'BCU 73' | 1997 | Irrigated (TS) | NWP, NEPZ, PZ | DWR Karnal |
| 'DWR 28' | 2002 | Irrigated (TS) | NWPZ | DWR Karnal |
| 'DWRUB 52' | 2007 | Irrigated (TS) | NWPZ | DWR Karnal |
| 'RD 2668' | 2007 | Irrigated (TS) | NWPZ | ARS (RAU) Durgapura |

*Better varieties amongst the six-row types

under AICW&BIP has got a major research component on the barley improvement for grain/feed purposes. A large number of varieties have been developed/released either by Central Varietal Release Committee (CVRC) or respective State Varietal Release Committees (SVRCs) for states addressing different production conditions and agro-climatic situations (Table 2) by different centers under AICW&BIP.

Incorporation of resistance to major diseases and pests along with improvement for grain yield has been the major objective of these centers. Some of improved varieties developed under this programme are given below. However, with the recent changes in climate conditions the programme will have to continue working hard to address the new

threats of change in disease dynamics and drought and heat stress to maintain/make further improvement in yield level.

Malt barley improvement

Research efforts on malt barley improvement in the country didn't receive attention earlier and only introduction of two-row malt variety 'Clipper' from Australia was made in 1969, which did not perform well under Indian conditions due to late maturity, grassy type and lodging problem under high input condition. With rise in industrial demand for malting, malt barley improvement programme was initiated in early nineties. Two more introductions 'ALFA 93' and 'BCU 73', both two row, good malt type varieties were released by CVRC in 1994 and 1997,

Table 4. Barley varieties for cultivation under saline-alkaline soils

| Variety | Year | Production condition | Area of adaptation | Developed by |
|--------------------------|------|----------------------|--------------------|---------------------|
| 'DL 88' | 1997 | Irrigated (TS & L S) | NWPZ | IARI, New Delhi |
| 'RD 2552' | 1999 | Irrigated (TS) | NWPZ, NEPZ | ARS(RAU), Durgapura |
| 'NDB 1173' | 2004 | Irrigated (TS) | NWPZ, NEPZ | NDUA&T, Faizabad |
| 'NBarley 1' ('NDB 209') | 1999 | Irrigated (TS) | Uttar Pradesh | NDUA&T, Faizabad |
| 'NBarley 3' ('NDB 1020') | 2001 | Irrigated (TS & LS) | Uttar Pradesh | NDUA&T, Faizabad |

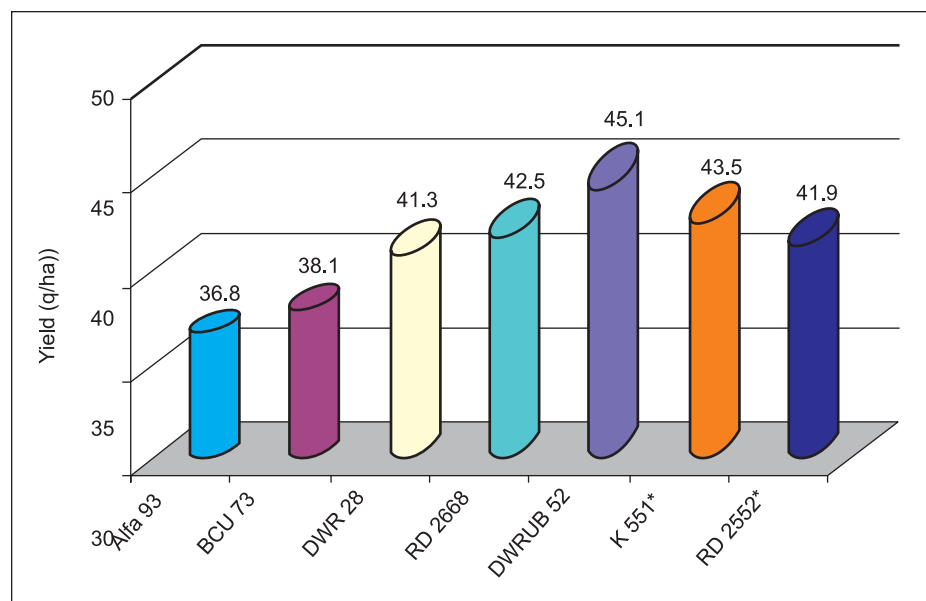
Table 5. Dual purpose barley varieties released in India

| Variety | Year | Production Condition | Area of Adaptation | Developed at |
|-----------|-------|----------------------|--------------------|----------------|
| 'RD 2715' | 2008 | Irrigated | Central zone | ARS, Durgapura |
| 'BHS380' | 2010 | Rainfed | NHZ | IARIRS, Shimla |
| 'RD 2035' | 1994* | Irrigated | NWPZ | ARS, Durgapura |
| 'RD 2552' | 1999* | Irrigated | NWPZ | ARS, Durgapura |

*These varieties were released as grain type earlier but recently observed as also good for dual purposes

Table 6. Important diseases of barley in India

| Disease | Causal organisms | Area of prevalence |
|-------------------------|------------------------------------|---------------------|
| Yellow rust | <i>Puccinia striiformis hordei</i> | All zones except CZ |
| Brown rust | <i>Puccinia hordei</i> | NEPZ & NWPZ |
| Black rust | <i>Puccinia graminis tritici</i> | Only in PZ |
| Spot blotch/Leaf blight | <i>Bipolaris sorokiniana</i> | NEPZ, NWPZ, PZ |
| Net blotch | <i>Pyrenophora teres</i> | NEPZ, PZ |
| Powdery mildew | <i>Erysiphegraminis hordei</i> | NHZ |



Yield gain in two-row barley through 2x6 r hybridization in NWPZ of India

respectively, for commercial cultivation in North Western Plains Zone (NWPZ) under timely sown conditions. However, late maturity, weak straw, poor grain filling under heat stress and low yield level still remained a major concern for its popularization among farmers, in absence of any premium by industry for quality. Some six-row type cultivars were released subsequently like 'RD 2503' for NWPZ, 'K 551' for NEPZ and 'DL 88' for Peninsular Zone for cultivation under irrigated timely sown conditions having good malting qualities amongst six-row barley. The minimum standards were also fixed for various malting quality traits of barley grain and malt in India as a guideline to breeders in mid nineties.

However, in order to make further improvement in malting type varieties, a comprehensive breeding and evaluation program was taken up under the Barley Network. These efforts resulted in the development of first indigenously bred two-row malt barley variety ('DWR 28') in the country, which was released by CVRC for commercial cultivation in North Western Plains Zone (Table 3). The continuous efforts for making improvement in quality and yielding ability resulted in two more high yielding two-row malt varieties ('DWRUB 52' and 'RD 2668'), which have been released subsequently in 2007 by CVRC.

These varieties are performing very well in farmer's field and gave yield comparable to best six row checks under optimum management conditions. These varieties are now being utilized by private companies for "Contract Farming" in Punjab, Haryana and Rajasthan to fulfill their increasing demand of raw material for malting.

Barley improvement for salinity tolerance

Barley is known for its inherent tolerance to salinity and alkalinity as

compared to other cereals. It has a good potential for problematic soils where otherwise it's very difficult to grow crop in winter season. There is a lot of area under such conditions in country. In Uttar Pradesh alone there are more than 1.2 m ha affected by salinity and alkalinity. It is also observed that there is a sharp rise in area under problematic soils. In order to meet the demand for such areas barley centers like Faizabad, Kanpur, Durgapura and Hisar are evaluating new varieties as they have good facility for salinity screening. However, it's a highly challenging task to screen materials for such conditions due to very high variability in the field condition affected by salinity and alkalinity. As a result the field screening for salinity tolerance sometimes can't be fully reliable, because of non-repetitive performance due to the soil heterogeneity. To have more efficient evaluation, we may have to look for the *in-vitro* screening for salinity- alkalinity tolerance to supplement the regular research efforts. The efforts of barley research workers under AICWBIP have resulted in development and release of many tolerant varieties (Table 4), which give good yield level under such unfavorable conditions also.

Dual-purposes barley for semi-arid areas

Barley grain has been traditionally used as animal feed and grain crop for human consumption in India. However, of late due to increasing scarcity of green forage availability in the arid and semi-arid region, it was observed that barley can be utilized as an alternative source of green forage in the drier parts of states like Rajasthan, Haryana, Punjab, MP and UP. Also in case of hills most of the farmers are growing barley in apple orchards mainly for utilization as green forage. The Barley Network took a new initiative during last few years to look at the possibility of utilizing barley as a dual purpose

crop to meet the requirements in association with AICRP-FC, Jhansi. It was found that barley crop can be given one cut (at 50-55 days after sowing in plains and 70-75 days after sowing in hills) for green forage and the regenerated crop can be utilized for grain purposes. A new series of yield trials was initiated from 2003-04 crop season for dual-purpose barleys in plains and hills zones to identify suitable genotypes. Already released feed type varieties 'RD 2035' and 'RD 2552' have been found equally good to be used as dual purpose type. Two more new varieties ('RD 2715' for central zone and 'BHS 380' for NH zone) have been released by CVRC as dual-purpose barley (Table 5). However, there is a need to continue working on this area to develop better variety to be used as dual-purpose barley. There is also a need for evaluation of the forage quality traits to improve the overall suitability as green forage. Thus barley can serve as supplementary crop for augmenting the green forage demand in the arid/ semi-arid areas of northern plains under limited irrigations and in hills under rainfed conditions. It also gives satisfactory levels of grain yield from the regenerated crop, which can also be utilized as feed for cattle feed or for human food.

Development of resource management technologies

Till early sixties agronomic investigations on barley in India centered mostly around varietal evaluation and mixed cropping trial or dates of sowing and rates of fertilizer application experiments as isolated efforts by few institutions. With initiation of All India Coordination Project on Barley in mid sixties, coordinated experiments on important agronomic aspects like rate, method and time of sowing, fertilizer and irrigation requirement of barley, were undertaken on zonal/ regional basis, which led to valuable

and useful results applicable to much wider areas. During early seventies more emphasis was laid on resource management in dryland barley research.

The research efforts were also initiated to solve the area specific and location oriented problems in barley production. The resource management requirements in irrigated, dryland, saline/alkaline, single and double cropped situations, timely and late sown conditions are quite different from each other. Numbers of specific problems under different situations have been addressed through approach. Recently research on resource conservation techniques and input management were initiated in barley as new initiative. Investigations in production technologies for dual-purpose barley were also necessitated with development of new set of varieties. The recommendations for stage of cutting for forage, fertilizer application (dose and time) and irrigation have been finalized. Despite of the fact that the crop being grown mostly on marginal and problematic lands, there is an increasing trend observed in the average grain productivity per unit area during recent years. This confirms the contribution of the improved technologies developed recently apart from the varieties.

Sowing method and seed rate

Although many farmers grow barley by broadcasting but the best method of seeding is by using ferti-seed drill for proper crop establishment and stand for good yield.

The spacing between lines should be kept 23 cm under irrigated conditions which should be reduced to 18 cm under late sown. For irrigated conditions a seed rate of 80-100 kg/ha is generally recommended while for rainfed conditions, the recommended seed rate is 70-75 kg/ha.

Fertilization

In general the fertilizers should be applied on soil test basis. However, it has been found in multilocation trials that the most of the six-row feed barley varieties respond up to 60 kg/ha nitrogen application under irrigated conditions, whereas under rainfed conditions the response is up to 40 kg N/ha. Therefore, the fertilizer @ 60:30:20 kg NPK/ha may be applied under irrigated conditions and for rainfed the rate of nutrient application should be 40:30:20 kg NPK/ha. For rainfed barley all the fertilizer should be applied at the time of seeding whereas under irrigated conditions half nitrogen and full dose of phosphorus and potash should be applied at the time of sowing and the remaining nitrogen should be applied with the first irrigation. The results showed that the two-row malt barley varieties responded up to 90 kg N/ha without adversely affecting the quality of the grain.

Irrigation

Traditionally barley has been grown in poor marginal lands without irrigation. In order to get optimum yield from malt barley varieties, 2-3 irrigations are sufficient, depending on the climatic conditions. In case of feed barley if water is limited and is available only for one irrigation, it may be applied at 30-35 days after sowing. If water is available for 2 irrigations, the second irrigation may be applied around spike emergence (60-65 days after seeding). The third irrigation, if available can be applied between 90-95 days after seeding normally at the grain filling stage.

Weed control

Barley is a fast growing crop and generally weeds may not compete with crop if proper crop stand is maintained. However, if required, isoproturon may be used for control of grassy weeds including the *Phalaris*

minor and for broad leaf weeds 2,4-D or metsulfuron can be used. The spray of these herbicides should be done after first irrigations at around 35 days after seeding. The common wheat herbicides like Leader and Pumasuper etc. should not be applied on barley as some of them may cause heavy losses in barley. Recently Pinaxaden (Axil) has been found effective against the isoproturon resistant types of *Phalaris minor* in barley.

Diseases and pest management

Barley is exposed to various diseases and insect pests responsible for heavy reduction in yield and quality. Though barley is attacked by many pathogens but few are economically important in India, which need attention through resistance breeding or chemical control. These includes rusts, leaf blights (spot and net blotch) and powdery mildew.

The seed-borne diseases like covered smut, loose smut and leaf stripe can also cause severe losses, but effective seed treatment is available.

During 1970's to late eighties the leaf blights were considered as a minor disease as most of barley was under rainfed cultivation in dry areas, but due to change in climate and cropping patterns and adoption of new technologies the disease levels of leaf blight have increased. In case of malt barley cultivation, application of more fertilizers under irrigated condition results in more foliage growth favoring build up of pathogens. In late sown barley the vegetative stage coincides with warm and humid condition during February and March and provides good spread of blights. In recent years, leaf blights assumed an important yield limiting factor in barley cultivation causing very heavy losses. Since both leaf spot and net blotch are multiple cycles, fast spreading disease, chemical control is not very effective and use of tolerant/resistant cultivars is a

better option for disease management. The crop rotation which allows the non-host crop in crop sequence can help in reduction of soil borne inoculum for blights.

General management practices

As barley is considered a poor man's crop and is being cultivated in marginal lands, use of resistant varieties are the best strategy to curtail the effect of diseases. In recent years, the cultivars with resistance are available to all three rusts and spraying the field with Folicur or Tilt @ 0.1% can give good control for the blight. Seed treatments with combination of Vitavax and Plantvax controls stripe disease, loose smut and covered smut. Crop rotation with non-host crops and removal of crop debris will also help in mitigating the barley disease problems. In general, for management of barley diseases, use of resistant varieties with minimum number of sprays of recommended chemicals is suggested, as it would be more economical. Based on the field experiments the IPM recommendation is given as follows:

- Seed treatment with Vitavax Power @ 3g/kg of seed followed by seed treatment with Gaucho @ 0.06 g a.i./kg of seed at sowing.
- Foliar sprays of Tilt (25 EC) @ 0.1% at the appearance of rusts and foliar blight and later at 15 days intervals in case if need arise till physiological maturity.
- Foliar sprays of Confidor @ 20 g a.i./ha at the appearance of foliar aphids and later at 15 days intervals till physiological maturity and as per need.

FUTURE CHALLENGES IN BARLEY PRODUCTION

Area constraints

Although barley area in India has more or less stabilized around 700-800 thousand ha over last decade after substantial decline from 3.5 m

ha during seventies, but challenges remain to keep this level and make further improvement in area to meet the increasing demand for industrial utilization, by making availability of high yielding better quality varieties. Also there will be increasing demand for feed and forage type barley varieties especially in the era of climate change where water availability will become a limiting factor for growing more water requiring crops like wheat.

Demand for quality raw material for malting

In India, barley is now becoming more and more important as commercial crop for industrial raw materials for malting and brewing. Although the proportion in malting utilization is less at present but it is expected to increase with changing scenario in south-east Asia with respect to rapid growth for beer and other malt based product consumption. The Barley Network under AICW&BIP has already taken up the specific research program on malt quality barley. The private-public partnership has been initiated in malt barley varietal improvement, development of malt quality standards for breeders and popularization of malt barley cultivation through joint demonstrations at farmer's fields.

The concept of "contract farming" has become a reality now in states like Punjab, Haryana and Rajasthan, where new two row malt type cultivars are being cultivated/ promoted by brewing industry, with premium prices for quality. Improvement in yield levels in such two row cultivars has made them at par with traditional six row feed barley cultivars, under optimally managed conditions. However, still there is a great need of popularization of such cultivars through joint efforts of industry as well as state department functionaries. The production system for such new cultivars through joint efforts shall

boost the malt barley cultivation through increased availability of quality seed.

Increasing area under problematic soils

The most commonly observed fact is that farmer will always prefer to grow wheat in resource rich conditions and push barley to problematic soils with minimum input. There is a big challenge to make yield breakthrough in barley varieties for abiotic stresses like salinity, drought and heat tolerance for near future under the changing climatic conditions. The new initiatives have been taken up by DWR, by evaluation of more than 5500 germplasm collections to discover better sources of tolerance to such stresses. There confirmed sources of abiotic stresses are ready for use in the future breeding programmes to address these important issues.

Supplementing the demand for feed/forage

It is visualized that barley is going to be an important crop in semi-arid region for supplementing the grain feed as well as for green forage, due to its limited water requirement and faster growth at early stages. The progress has been made in this regard through association of AICRO-FC, Jhansi by developing/identifying dual-purpose barley varieties for such areas. However, still there is a need for better biomass and nutritional quality of the barley forage. Germplasm evaluation for such traits is the need of the hour to identify good sources for further improvement in this field.

Resource management in changing scenario

The most important aspect of study in barley agronomy still remains to be covered is the detailed nutrient and moisture utilization pattern under different situations supported by physiologic and

economic studies. No doubt, barley's input requirement is low but how to raise the input efficiency in crop production is another challenge. Plant type of two-row fertilizer responsive malt barley varieties has widened the scope of raising the production potential of this crop, through agronomic research in near future. Agronomic research on malt barley, hulless barley, feed and forage barley, barley saline and coastal lands needs to be undertaken on priority. There is need to develop lodging resistant varieties as barley is prone to lodging under high input application. There is also a need for taking up the experiments on furrow irrigated raised bed (FIRB) system in barley, especially with new plant type varieties to avoid lodging, as well as for faster irrigation, which can be of much use in larger seed production plots in particular.

Disease/pest management in changing cultural practices and climates

Incorporation of varietal resistance for prevailing disease has been the main objective of the barley improvement programme under barley network. The joint efforts of the breeders and pathologists have resulted in development of resistant/tolerant varieties. The two major aspects for resistance breeding were rusts and leaf blights. The relative emphasis may differ according to area of cultivation (zones) and production conditions in years to come. In case of northern hills zone (NHZ) resistance to yellow rust is and will continue to be the primary requirement for new varieties, since it will cut down the inoculum load for plains. In lower hills again leaf rust is very important and resistance is always essential. In addition powdery mildew is another important disease needs to be focused in coming future. In case of north western plains zone (NWPZ) resistance to both yellow and brown rusts are critical for new

varieties. Recently with introduction of irrigated barley cultivation in NWPZ, the levels of leaf spot in various parts has raised except the semi-arid belt of Rajasthan. The movement/spread of inocula of leaf blights from eastern areas with seed have further complicated the situation.

In north eastern zone (NEPZ) leaf rusts, spot and net blotch are very important with warmer and humid climate. The changing climatic conditions are likely to increase blight diseases on much larger scale. Since the inocula can survive through crop residue in soil, this can further complicate the situation. Therefore we may have to follow more strict norms of field resistance in new cultivars to avoid disease build up and spread.

New stable sources of resistance

Though the available barley varieties are showing some amount of resistance against all three rusts but unfortunately they lack good resistance to leaf blight. Thus there is a need for identifying sources of blight resistance from germplasm by screening with our leaf blight isolates. The sources of resistance from wild species and grasses have to be searched for incorporating the same into cultivated barley.

SUMMARY

Barley cultivation in India was facing stiff challenges in terms of area with wheat in winter season, as the crop was considered less remunerative due to less MSP and market price, resulting drastic reduction in area and production. Recent changes in

situation triggered by the industrial demand in malting and brewing has given it a new lease of life and it is becoming commercial crop. Contract farming on larger scale has started in Punjab, Haryana and Rajasthan. The new challenges for production and protection technologies in addition to the genetic improvement are being envisaged because of its shift to optimally managed conditions. We may also have to look for lodging resistance through new plant type in addition to the requirements of genetic resistance to biotic and abiotic stresses and better grain quality. The changing climate and shortage of water are general problems of crop production and barley cultivation can be a good option to mitigate with such challenges. ■

Future strategies for enhancing nutritional quality of wheat

Out of total world wheat production, around 25% wheat is traded and it is dominated by USA, Australia, Canada and Argentina, which account for 75% of the total exports. The major importers are Iran, Brazil, Japan, Algeria, Egypt, European Union, Indonesia, South Korea, Morocco and Philippines etc. Indian share in global export is very less and also inconsistent. Wheat is procured as a mixture of varieties called mill Dara under FAQ norms in India. No separate procurement by varieties/grades/ classes is done. To compete in international markets the procurement standards need to be reframed. Procurement by varieties/grades/classes and their storage in separate godowns/silos shall have to be taken on a war footing. The Food Corporation of India (FCI) shall have to procure wheat at *mandis* and keep it as segregated lots in silos after cleaning and grading for release to agencies engaged in export. To effect procurement variety/classwise, FCI would need strong quality testing/ varietal identification support either from its own set up or from Indian Council of Agricultural Research (ICAR) Institutes/Agricultural Universities. Millers/bakers/traders/ export agencies may directly procure the grains at farm gate and do their own grading, cleaning and quality testing. Some of the constraints faced by the millers like inconsistency in quality of raw materials, high energy cost, obsolete machinery, lack of storage facilities for raw materials and finished products, financial capabilities for purchase of raw material, lack of human resource development by training the people on scientific lines, and procurement restrictions by the government form time to time which causes distorted performance in terms of capacity utilization and value addition should be addressed to make them venture into innovative approach of producing flours of international standard. Some of the administrative issues related to promotion of wheat export can be grouped as up-gradation of quality related facilities at *mandis* and ports, contract farming, segregated procurement, transportation and storage, market intelligence and pricing policy which should provide premium to farmers for high-protein wheats like sugar mills pay premium for higher sugar content in sugarcane, adequate linkages between research and industry.