

Climate-Smart Seed Production Technology of Barley for Indian Agricultural Environments

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ABSTRACT

Climate-Smart Agriculture has emerged as an important approach to address the growing challenges posed by climate change, resource limitations and climate-related stresses in agricultural production. Barley (*Hordeum vulgare* L.) is an important Rabi cereal crop used for food, feed, malt and various industrial purposes. Its ability to perform well under drought, salinity, marginal soils and low-input conditions makes it a promising crop for climate-resilient agriculture. In India, barley production is mainly concentrated in Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh and other northern and central regions, although considerable differences in area, production and productivity exist among states. This assessment assesses climate-smart technologies for barley seed production under Indian conditions, with emphasis on varietal selection, quality seed sources, seed treatment, land preparation, timely sowing,

nutrient and irrigation management, weed and pest management, field inspection, rouging, isolation, harvesting, seed processing, storage and certification. Practices such as efficient water management, laser land levelling, balanced nutrient application, integrated pest and disease management, conservation-oriented tillage and energy-efficient technologies can improve resource-use efficiency and production stability. Regular field inspection and timely rouging are important for maintaining genetic purity, while proper seed processing and storage help preserve seed viability and quality. The review also highlights key grain and seed quality traits, including kernel appearance and color, hull characteristics, uniformity, nutritional composition and suitability for food and malting purposes. Overall, combining quality seed production with climate-smart agronomic and resource-management practices can improve barley productivity, seed quality, genetic purity, resilience and sustainability, while supporting long-term food and nutritional security under changing climatic conditions.

Keywords Smart agriculture, Barley, Seed production, Nutritional value, Grain color.

INTRODUCTION

Climate change is one of the important areas of concern globally to ensure food and nutrition security to the growing population. As per the latest report, the global average temperature rise is 0.99°C (NASA, 2016) since pre-industrial time (1850). Global warm-

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ing is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate (Bhusal *et al.* 2020). Warming greater than the global average is being experienced in many land regions and seasons and it is 2 to 3 times higher in the Arctic. The year 2016 ranks as the warmest year and 16 of the 17 warmest years in the 136 year record all have occurred since 2001. The number of cold days and nights has decreased and the number of warm days and nights has increased globally. Frequency of heat waves has increased in large parts of Europe, Asia and Australia. Global sea level has risen by 0.19 m between 1901 and 2010. (Ravindra Chary G. 2019) Barley (*Hordeum vulgare* L.) crop is a cereal and is associated to *Poaceae* family. It is termed as common barley, cereal barley or grain barley, Jau (in Hindi). Barley is cultivated majorly as *Rabi* season crop in northern plains of India. *H. spontaneum* which is a weedy plant is presumed as the ancestor of cultivated common barley. Barley crop is of paramount importance and ranks fourth in top cereal crops produced in the world after wheat, maize, and rice (Singh *et al.* 2021 and Akar T. *et al.* 2004). The leading countries of its production are USSR, China, France, Canada, USA and Spain. The major barley growing regions in India are Central parts of eastern Uttar Pradesh, Eastern parts of Rajasthan and North western parts of Bihar. As barley is harder than wheat and is inherently equipped to adapt itself admirably well under limited inputs and marginal lands. It can be grown in diverse agro climatic conditions like drought, salinity, alkalinity, rain-fed or irrigation ecosystems, plains or hilly areas where owing to some agro – climatic constraints wheat cannot be grown successfully. Barley is also suitable for late sown condition. Since production capacity of the crop may be more however, the capacity of this crop is not high at present. Therefore, pushing up the production good production technology should be practiced. Barley is under cultivated in the Andes on mountain slopes, Tibet, Nepal, Ethiopia, as rain fed crop in North Africa, Afghanistan, Pakistan and the Middle East. There are many crop wild relatives found in Barley. *H. vulgare subsp. spontaneum* and *H. marinum* is tolerant to drought and salt and are wild relatives for barley improvement. *H. bulbosum* species of barley is resistant to Barley Yellow Dwarf Virus and Stem Rust (Anonymous 2020a). The grain of barley is a huge source of energy as it has a low

glycemic index that provides slow but continuous release of energy which is must for survival in the high treacherous altitudes. In comparison to rice or wheat the total number of cells in endosperm of barley seed is higher therefore it consists of higher proportions of β glucans (Singh *et al.* 2021 and Australian Government 2008). There are many health benefits of barley diet for curing anemia, bone disorder, lower cholesterol, type-2 diabetes and kidney stone. For some part of the global population is allergic to barley that is seen in form of Coeliac disease (Gluten-sensitive enteropathy) due to intolerance due to gluten from barley, wheat, rye etc. (Australian Government 2008). Without exception barley crop is adapted to grow in stress-prone environments and marginal lands. No doubt it is type of crop that falls under the category of risk-avoidance crop. Barley varieties or species is classified in different ways by Crop Wild Relative official (CWR -diversity) e.g. two, four or six-row types, number of fertile seeds per spikelet; awns covering or not covering the kernels it can be normal (hooded), elevated (hooded), long awned or shortened; presence of hull or absence (naked); use (food, feed or malt); height i.e., tall and dwarf and seed color i.e., white, blue, colorless, or yellow.

Conceptual framework of Climate-Smart Agriculture

CSA consists of three pillars which are described below:

Adaptation

Adaptation refers to reducing the vulnerability of climate change-induced disaster by altering the exposure, reducing sensitivity and increasing the adaptive capacity. Examples:

If a particular site faces drought conditions, then one of the adaptation strategies that one can adopt is the use of drought-tolerant crop varieties. Furthermore, the promotion of different water-efficient technologies including drip irrigation could be other strategies to produce crops under water-limited conditions.

Similarly, farming communities in flood-prone areas can prepare raised nursery beds to protect seed-

lings from submergence.

Mitigation

Mitigation refers to the reduction of the emission of greenhouse gases and enhancing carbon sequestration for long term storage of atmospheric carbon dioxide. Examples:

Use of zero tillage/minimum tillage technology can reduce GHGs emissions from the volatilization of organic soil carbon.

Integrated nutrient management can reduce emissions by reducing the excessive use and loss of chemical fertilizers and thus improves nitrogen use efficiency through precision farming systems.

Use of Leaf color chart helps calculate the exact amount of nitrogen required by the plants and reduces excessive use of fertilizers.

Use of cover crops and incorporation of crop residues into the soil can generate higher inputs.

Use of a solar-based irrigation system can replace

the diesel pump-based irrigation system that can significantly reduce GHGs emission.

Productivity

CSA aims to maintain and improve agricultural production and productivity under adverse climatic condition through the promotion of different climate change adaptation-related technologies and practices (Bhusal *et al.* 2020) as given (Table 1).

Scenario for Barley in India

Barley, a competing crop to wheat, has shown a similar pattern in area and production scenario with regional differences across states. For the *Rabi* 2023-24 crop season, barley production witnessed a decrease by 2.59 lakh tonnes (Source: III Advance Estimate from the Directorate of Economics and Statistics, Ministry of Agriculture and Farmer's Welfare, India). The decline in production is attributed to the area decrease by 12.24 % (-0.76 lakh hectares) and reduction in the yield level by 0.01% (-46 kg/ha). Year-to-year area under barley has witnessed a mixed pattern, but the long-run decline in barley area is a

Table 1. Comparison of current agricultural practices and climate-smart agriculture.

Current agricultural practices		Climate-Smart Agriculture
Land	Expand agricultural area through deforestation and converting grasslands to cropland.	Increase land utilization by converting degraded land to cultivable land (e.g. through solar-based irrigation) and reduces land degradation otherwise caused by heavy tilling (by using zero or minimum tillage) or similar ones.
Natural resources	Make the most use out of natural resources - the land, water, forests, and soils used in production -without paying much attention to their sustainability over the long term.	Restore, conserve and use natural resources sustainably.
Varieties	Rely on a few crops and/or a few high yielding improved and hybrid crop varieties and improved breeds.	Use a mix of traditional and modern, locally adapted varieties and breeds to maintain output, increase yields and ensure their stability in the face of climate change.
Inputs	Relentless use of fertilizer, pesticides and herbicides.	Improve the efficiency of agrochemical use. Control pests, diseases and weeds using integrated management approaches. Priority is given to the application of compost manure and green manure. Rotate crops with legumes to fix nitrogen and reduce the use of chemical fertilizers.
Energy	Use farm machinery that usually relies on fossil fuels – such as tractors and diesel pumps.	Use energy-efficient methods, such as solar- based irrigation and biofuels.
Production and marketing	Specialize in production and marketing to achieve greater efficiency.	Diversify production and marketing to add stability and reduce risk.

Source Climate-Smart Agriculture (CSA) Training Manual (2020)
(<https://cgspace.cgiar.org/items/4efa0c27-8f14-49e7-8485-50a769cdf0f4>)

Table 2. Area, production and Yield of barley crop.

Year	Area (lakh ha)	Production (lakh tone)	Yield (Kg/ha)
2021-22	4.53	13.71	3025
2022-23	6.28	19.13	3044
2023-24	5.51	16.99	3082
2024-25	6.08	19.19	3159

Source Ministry of Agriculture & Farmers Welfare
(<https://upag.gov.in/dashreports/allindiaapy>).

major concern since barley sowing depends on the demand (household and market) as well as its economic returns in comparison to the other competing Rabi crops. Among barley growing state, Rajasthan holds the top slot in production (1.02 million tonnes) followed by Uttar Pradesh (0.44 million tonnes), Haryana (0.04 million tonnes) and Madhya Pradesh (0.03 million tonnes), given as (Table 2 & 3) The aforementioned four states altogether accounted for about 92% of the total barley produced in the country. Rajasthan consecutively ranks first in terms of barley acreage (0.28 million hectares) during 2023-24 Rabi season, the average productivity in barley was highest in the case of Haryana (3385 kg/ha), followed by Punjab (3883 kg/ha) and Rajasthan (3603 kg/ha). The aforementioned states registered the productivity levels more than the national average (2998 kg/ha).

Among barley growing states, a wide range of variation has been noticed in crop acreage, production and productivity levels. Productivity has declined in

states like Bihar, Chhattisgarh, Haryana and Uttar Pradesh ranging from 103 to 464 kg/ha. The crop acreage has witnessed a mixed pattern in all over country with increasing trend in Bihar, Chhattisgarh, Punjab and Uttarakhand and decreasing trend in Rajasthan, Uttar Pradesh, Haryana, Himachal Pradesh Madhya Pradesh and West Bengal. Surprisingly, Punjab is the only state that has exhibited a positive change in all the three variables viz., area, production and productivity of barley. The increase in barley output was registered in Himachal Pradesh (7.35%) followed by Punjab (4.61%) The overall productivity of the country fell down by 46 kg/ha. The highest decline was recorded in Uttar Pradesh (464 kg/ha). The maximum gain in yield was observed in Rajasthan (200 kg/ha). (ICAR-IIWBR 2024).

Classification of species of Hordeum

There are about 33 species under genus *Hordeum* with basic chromosome number seven Varietal seed production in barley is commercially viable since crop is highly self-pollinated with a minimum of 0-9% out crossing. For the development of hybrid seeds method of emasculation and pollination as well as male sterility can be employed. Barley hybrids can be developed by using a genetic recessive gene for male sterility in a balanced tertiary trisomic system (Table 4) (Singh *et al.* 2021 and Ramage 1965).

Morphology of the crop

The botanical description of main parts of barley

Table 3. State-wise Area, production and Yield of barley crop.

State	Area (Million ha)	2022-23 Production (Million tonne)	Yield (kg/ha)	Area (Million ha)	2023-24 Production (Million tonne)	Yield (kg/ha)
Bihar	7.21	12.44	1727	7.24	11.76	1624
Chhattisgarh	0.81	0.75	922	0.86	0.63	727
Haryana	12.87	45.98	3573	11.42	38.66	3385
Himachal Pradesh	17.25	27.33	1579	17.19	29.34	1707
Madhya Pradesh	24.00	38.71	1613	19.00	32.97	1735
Punjab	5.0	19.30	3859	5.20	20.19	3883
Rajasthan	330.75	1125.56	3403	285.06	1027.08	3603
Uttar Pradesh	193.00	592.12	3068	171.00	445.26	2604
Uttarakhand	20.00	28.42	1421	18.46	26.24	1421
West Bengal	0.12	0.22	1860	0.10	0.19	1850
Others	17.31	22.09	1882	15.83	20.19	1321
India	628.32	1912.92	3044	551.37	1653.22	2998

Sources Director's Report 2023-24 IIWBR Karnal Haryana).

Table 4. Classification of species of *Hordeum*.

Common name	Scientific Name	Ploidy level	Chromosome no.
Grain barley	<i>Hordeum vulgare</i> L. spp. <i>vulgare</i>		
Wild barley	<i>H. vulgare</i> L. spp. <i>spontaneum</i>	Diploid	$2n = 2x = 14$
Argentine barley	<i>H. euclaston</i>		
Centenilo	<i>H. stenostachys</i>		
Bulbosum barley	<i>H. bulbosum</i>	Tetraploid	
Cape wild barley	<i>H. capense</i>		$2n = 4x = 28$
Meadow barley	<i>H. brachyantherum</i>	Hexaploid	
Arizona barley	<i>H. arizonicum</i>		$2n = 6x = 42$
Classification based on fertility of spikelets			
Two rowed type (<i>Hordeum distichon</i> L.)	In the two row barley the two lateral spikelets are sterile, thus each spike has only two vertical rows of kernels		
Six rowed type (<i>Hordeum Vulgare</i> L.)	In six row barley both the florets are fertile both the lateral florets are fertile but their size may vary from slightly to moderately smaller than the central floret		
Irregular type (<i>Hordeum irregular</i> L.)	Central florets are fertile, whereas the lateral florets are reduced to rachilla		
Classification based on awns			
Awned type	Presence of awns takes place on grains		
Awnless type	These are also called hooded because of the hood shaped structure that develops in place of awn.		
Classification based on adherence of chaff to grain			
Hulled type	In this category floral glumes remains attached to grains resulting in poor flour making.		
Hull- less	In this type husk readily falls after threshing and naked grains free of chaff can be obtained.		

plant is given below:

Root System: It consists of shallow and deep roots. The shallow roots arise near the soil surface spread laterally about 15-30 cm while the deep root extends downwards in deep layers of soil may be from 0.75 to 150 cm.

Stem (Culm): The stem is cylindrical and contains 5 to 7 hollow internodes separated by solid nodes.

Leaves: Leaves are usually broader and of lighter green color than wheat. Each leaf consists of a sheath, ligule and auricle.

Inflorescence: The inflorescence is called spike or head. Each spikelet has two glumes and a floret with three stamens and a pistil with a single ovule and a stigma.

Kernel (Grain): The grain of barley is a caryopsis composed of the pericarp, endosperm and endosperm.

Soil requirement

Sandy loam to loamy sand soils of Indo-Gangetic plains having neutral to mild saline reaction and medium fertility are the most suitable types for barley cultivation, however, it may be grown on a variety of soil types, viz; saline, sodic and lighter soils. Being salt resistant, its cultivation has become possible on saline coastal areas of Sunderban in West Bengal and saline black soils of canal irrigated areas of northern Karnataka. (Singh *et al.* 2014).

Climate requirement

Barley crop requires a temperate to subtropical

climatic condition for its proper growth and development. During growth period it requires 12-15 °C temperature and around 30°C at the time of maturity (Anonymous 2017). In India it is grown as a winter annual and cool springs hence the amount of moisture required by the crop for transpiration is not as much as it is needed for dry or warm season. During crop growth barley demands at least 4 inches of water or 450-650 mm/total growing period (120 to 150 days) from crop germination to the reproductive or grain filling stage. This stage is most essential stage of seed development (Singh *et al.* 2021, Ross and Shelley 2011). Predominantly barley grain is cultivated in the rainfed conditions in the northern hills of India where in farmers have low agricultural inputs. But this crop proves to be a boon in such areas as water requirement of this crop is low. The best time of sowing of the seeds is between 15th October to 10th November for irrigated conditions and in second fortnight of October for rainfed conditions to utilize the residual moisture from the monsoon rains.

Land Requirement

Land selected for a certified seed production should be free from weeds, volunteer crops plants and it should be well isolated from fields of same species. The total area on which seed production has to be

taken up should be registered under State Seed Certification Agency. Field should be first ploughed by disc harrow or soil turning plough to uproot weeds and kill over wintering pests and weeds. Then after precisely leveling the land irrigation is done before sowing. Barley crop is sensitive to water and nitrogen hence proper leveling of land using laser land leveler should be done before sowing. The field may attain optimum soil moisture after 5-15 days of irrigating depending on soil type. Afterwards two to three ploughings is done with harrow to make soil well pulverized (Randhir *et al.* 2014).

Selection of genotype/ Varieties

Most of the farmers even today are growing old barley varieties like Manjula, Azad, Jagriti (UP), BH 75 (Haryana), PL172 (Punjab), Sonu & Dolma (H.P.) though their yield is quite low. Under such conditions farmer have to grow new varieties to get a better yield. (Table 5). An appropriate variety should be selected as per the requirement of the area, climatic & environmental conditions and use. In case of barley cultivation for industrial uses, proper malt type variety may be selected.

Selection of Seed source and seed treatment

Generally, Farmers have to use quality seed from

Table 5. Improved Barley varieties for different production conditions in India.

Varieties	Production Conditions	Utility
RD 2794*	Irrigated, Timely sown, Salt tolerant	Feed
BH 946	Irrigated, Timely sown	Feed
DWRB 92*	Irrigated, Timely sown	Malt
DWRUB 52*	Irrigated, Timely sown	Malt
RD 2668*	Irrigated, Timely sown	Malt
RD 2035	Irrigated, Timely sown, Nematode resistant	Food & fodder
RD 2552	Irrigated, Timely sown	Food & fodder
RD 2715	Irrigated, Timely sown	Food & fodder
RD 2552	Irrigated, Timely sown	Food & fodder
RD 2715	Irrigated, Timely sown	Food & fodder
BH 902	Irrigated, Timely sown	Food
BH 393 (Haryana)	Irrigated, Timely sown	Food
PL 426 (Punjab)	Irrigated, Timely sown	Food

North Western Plains Zone (NWPZ): Punjab, Haryana, Delhi, Rajasthan (except Kota and Udaipur regions), Western UP, Tarai regions of Uttarakhand, Jammu and Kathua district of J&K and Una and Paonta valley of HP.(Singh *et al.* 2014).

Table 5. Continued.

Varieties	Production Conditions	Utility
RD 2592 (Rajasthan)	Irrigated, Timely sown	Food
RD 2052 (Rajasthan)	Irrigated, Timely sown, Nematode resistant	Food
ND B 1173	Irrigated, Timely sown, Salt tolerant	Food
DWRB 91*	Irrigated, Late sown	Malt
DWRB 73	Irrigated, Late sown	Malt
DWRUB 64	Irrigated, Late sown	Malt
RD 2508	Rainfed, Timely sown	Food
RD 2624	Rainfed, Timely sown	Food
RD 2660	Rainfed, Timely sown	Food & fodder
PL 419 (Punjab)	Rainfed, Timely sown	Food
DWRB 219	Irrigated conditions. Timely sown and Resistant to rust and & moderately tolerance to lodging.	Malt

North Eastern Plains Zone (NEPZ): Eastern U.P., Bihar, Jharkhand, Odisha, West Bengal, Assam and Plains of North Eastern States.

Varieties	Production Conditions	Utility
BCU 73*	Irrigated, Timely sown	Malt
K 551	Irrigated, Timely sown	Malt
RD 2794*	Irrigated, Timely sown, Salt tolerant	Feed
RD 2552	Irrigated, Timely sown, Salt tolerant	Food & fodder
NDB 1173	Irrigated, Timely sown, Salt tolerant	Food & fodder
K 508 (UP)	Irrigated, Timely sown	Food
NarendraBarley-1 (UP)	Irrigated, Timely sown, Salt tolerant	Food
NarendraBarley-3 (UP)	Irrigated, Timely sown, Salt tolerant	Food
NarendraBarely-2 (UP)	Irrigated, Late sown	Food
K 560	Rainfed, Timely sown	Food
K 603	Rainfed, Timely sown	Food
JB 58 (MP)	Rainfed, Timely sown	Food

Northern Hills Zone (NHZ): Western Himalayan region of J&K (except Jammu & Kathua district), HP (except Una district and Poanta valley) Uttarakhand (except Tarai Regions) and Sikkim.

Varieties	Production Conditions	Utility
BHS 400	Rainfed, Timely sown	Feed
UPB 1008	Rainfed, Timely sown	Feed
VLB 118	Rainfed, Timely sown	Food
HBL 113*	Rainfed, Timely sown	Food
HBL 276**	Rainfed, Timely sown, Resistant to cold and rust diseases	Food & fodder
BHS 169	Rainfed, Timely sown	Food
BHS 380	Rainfed, Timely sown	Food
BHS 352**	Rainfed, Timely sown	Food
HBL 316 (HP)	Rainfed, Timely sown	Food

Table 5. Continued.

Varieties	Production Conditions	Utility
VLB 56 (Uttarakhand)	Rainfed, Timely sown	Food
VLB 85	Rainfed, Timely sown	Food
Central Zone (CZ): MP, Chhattisgarh, Gujarat, Kota & Udaipur district of Rajasthan and Bundelkhand region of UP.		
Varieties	Production Conditions	Utility
RD 2786	Irrigated, Timely sown	Food
PL 751	Irrigated, Timely sown	Food
RD 2715	Irrigated, Timely sown	Food & fodder
JB 58 (MP)	Rainfed, Timely sown	Food
Peninsular Zone (PZ): Plains of Maharashtra & Karnataka.		
Varieties	Production Conditions	Utility
DL 88	Irrigated, Timely sown	Malt
BCU 73*	Irrigated, Timely sown	Malt

* Two row barley; ** Huskless Barely

better production. The better quality seeds could be obtained from National Seed Corporation (NSC), State Seed Farm Corporation (SFCE), research institutions agricultural universities and Krishi Vigyan Kendras (KVKs).

Seed treatment is very essential to control the seed born diseases in barley crop. For the control of loose smut (Kangari), seed should be treated with Vitavax or Bavistin @ 2g/ kg seed. The covered smut can be controlled by seed treatment with 1:1 mixture of Thiram + Bavistin or Vitavax @ 2.5g per kg or 1gm Raxil/kg seed. Termite problem is observed in many fields; treat the seed with 150 ml of Chloropyrifos (20EC) or 250 in 5 liter of water for 100 kg of seeds to avoid the loss due to termite attack. Among the physical treatment seed thermal treatment with hot vapors (100°C) for one to 10 seconds on spring barley can reduce fungal infection (Fusarium, Alternaria, Penicillium) and improve seed germination. (Singh *et al.* 2021 and Semaškieñė R. 2008).

Land requirement and its preparation

Land selected for seed production should be free from weeds, volunteer crops plants and it should be well isolated from fields of same species. The total area on which seed production has to be taken up should be registered under State Seed Certification Agency.

Field is prepared with disc harrow and cultivator followed by planking. As barley is sensitive to nitrogen and water hence, field should be well leveled. Leveling of field with laser land leveler is must for proper distribution and saving of water. Bunds are made to harvest and retain rain water in the field. In irrigated areas, field should be prepared after pre sowing irrigation for proper germination. Farmers can sow barley on raised beds too with a specially designed raised bed planter for saving of seed, fertilizer and water.

Fertilizer application

In irrigated areas, $\frac{1}{2}$ N+ full P and K at the time of sowing and remaining $\frac{1}{2}$ N after first irrigation. In rainfed condition, full NPK should be applied as basal at the time of sowing. In case of Zn deficiency, apply Zn SO₄ @ 20 kg/ha. (Table 6) Application of other micronutrients should be done on the basis of soil testing and deficiency symptoms

Method of sowing

Sowing with a seed cum fertilizer drill is the best method of sowing. Another traditional method of line sowing in some areas is dropping seeds with a Chonga (a tube connected with a funnel like structure behind country plough) attached to a desi-plough is

Table 6. Seed rate, time of sowing, spacing and fertilizer requirement.

Production condition	Seed rate (kg/ha)	Time of sowing	Spacing (cm)	Fertilizer requirement (kg /ha)
Irrigated Condition				
a) Timely sown	100	1-25 Nov.	23	60 N:30 P:20 K
b) Malt	100	1-25 Nov.	18-20	80 N:40 P:20 K
c) Late sown	100	1-25 Dec.	18-20	60 N:30 P:20 K
Rainfed Condition				
Plains	100	25 Oct.-10 Nov.	23	30 N:20 P:20 K
Hilly Region	100	20 Oct.-7 Nov.	23	40 N:20 P:20 K

In case of bold seeded varieties, seed rate should be kept higher. N=Nitrogen, P=Phosphorous, K=Potash.

also popular. Dropping seeds in open furrows behind desi-plough and broadcasting are found to be inferior compared to line sowing with seed drill. Soil should be made compact by planking or running a roller for better seed-soil contact.

Irrigation Management

Barley can be grown under irrigated, rainfed and limited irrigation conditions. Generally it requires 2-3 irrigations for better yield. The malt barley requires 3 irrigations to ensure better yield, grain uniformity and grain quality. Depending upon the water availability irrigation should be given at suitable stages (Table 7). In dry area of Rajasthan the number of irrigation should be increased to 5-6.

Growth stages of the crop

Germination: This stage is marked by the exhaustion of endosperm and initiation of crown root. This stage lasts up to 20 - 25 days from sowing.

Tillering: The seedling after initial establishment of crown root system starts tillering. This phase of growth may continue up to 30-35 days after sowing.

Table 7. Irrigation Schedule at various stage in Barley crop.

No. of irrigation	Days after sowing	Stage of crop
1	30-35	CRI
2	30-35, 65-70	CRI, Panicle emergence
3	30-35, 65-70, 90-95	CRI, Panicle emergence, Grain formation

Jointing: It is called shooting. Here the plant develops its vegetative part. Jointing may last up to 55 - 65 days after sowing.

Heading or flowering: This stage is known as earing and ear head emergence. This stage ends with the production of watery ripe grains. The crop will be in this phase up to 75-85 days after sowing.

Ripening: This stage includes the sub-phases of post milking, grain filling and grain development. The soft dough turns dough. This stage lasts up to 90-100 days after sowing.

Maturity: In this stage the plants losing moisture and plants to dry, the plants turn yellowish, loose stiffness and become droopy. The physiological maturity of the seed is completed and ready for the harvest. (Pandey 2022).

Isolation distance Requirements

Isolation is necessary not only from the context of maintenance of genetic purity, but it is also required to be maintained from certain crops and varieties especially in some countries for the control of such diseases as loose smut, caused by *Ustilago nuda*. The seed fields of barley for varietal/hybrid seed production shall be isolated by the distance given in following (Table-8) from the contaminants (Singh *et al.* 2021 and Anonymous 2013).

Field Inspection

Field inspection is done three times. First before sow-

Table 8.: Isolation Requirement for Barley Seed Production Fields.

Contaminants	Minimum distance (meters)			
	Varietal seed Found-	Certified aation		
Fields of other varieties/ commercial hybrid of the same variety	3	3	200	100
Fields of the same variety/ Hybrid not conforming to varietal purity requirements for certification	3	3	200	100
Fields of barley with infection of Loose smut disease in excess of 0.10% and 0.50% in Foundation and Certified seed respectively	150	150	200	150

ing the seeds to ensure the field meets the requirement of minimum area for certification, isolation distance, volunteer crops plants etc. and also at early vegetative growth. Second inspection at the 75 % flowering or spike emergence stage and third at maturity or before harvesting. If the off-type plants were removed after stage of flowering is over then all the plants that surrounds in 0.5 meter should be removed and discarded in case of hybrid seed production by CMS to ensure seed genetic purity.

Rouging

Rouging is very crucial operation at all the stages of field inspection. It is practically impossible to rouge out thousands of hectares of area together hence it is always preferred to practice roughing on smaller area of seed production (W. P. Feistritz 1975). Rougu-

ing is done at different stages 2-3 times in the seed production plot of barley at vegetative, flowering and before harvesting stage. Each time with the objective of removing a distinct off type, the entire plant should be removed along with all the tillers. In this way making several passes in the field each time to remove a specific type of weed or off type is proven beneficial for a successful rouging operation. Although if seed is brought from the authorized source, then there will be little need to do roughing as the seed will be free of any off type or admixture plant. Plants that are rouged out from barley seed production plots are Wild oats (*Avena fatua*), Gulli danda (*Phalaris minor*), Wheat (*Triticum aestivum*) and any other volunteer plant from previous season crop. Barley plant can be effectively rouged out from other varieties by looking into the characteristics type viz., vegetative characters (plant height, Growth:- Erect Semi-prostrate Prostrate, Flag leaf present/absent, Flag leaf waxiness), floral character (spike type-Two or six rowed, flag leaf length, awn tip pigmentation) and grain character (colour, hullness, shape). (Anonymous 2007). When rouging is completed, it should be confirmed that remaining plant matches the description of the variety.

Weed control measures

Barley is a fast growing crop and generally weeds may not be able to compete if proper crop stand is maintained. If the necessary weed control measures can be taken up (Table 9).

Some Important points for weed management

Always use weed free seeds for sowing.

Table 9. Type of weed and herbicides use, doses and mode of use in barley crop for seed production.

Nature of weeds	Name of Herbicides	Dose/ha	Method of application
Narrow leave			
<i>Avena fatua</i> (Wild Oat), <i>Phalaris minor</i> (Kanaki), Poa ghas, Lomar ghas	Pinoxaden (Axial 5 EC)	87.5 ml	30-35 days after sowing in 300 litres of water for one hectare
Broad leave			
<i>Chenopodium album</i> (Bathua), kharbathu, jangali palak, maina, metha, malwagrass, makoi, kandai, <i>Convolvulus arvensis</i> (hirankhuri), <i>Anagalis arvensis</i> (krishna neel), <i>Cronopus didymus</i> (wild carrot), pyaji, chatari-matari	Metsulfuron Algrip 2-4D (Weedmar)	10gm 1250 gm	30-35 days after sowing in 300 litres of water for one hectare

Table 9. Continued.

Nature of weeds	Name of Herbicides	Dose/ha	Method of application
Both (broad and narrow leave)	Isoproturan (Iso Guard 75 WP)	1250 gm	30-35 days after sowing in 300 litres of water for one hectare
	Pendimethalin (Stomp)	3125-3750 ml	3 days after sowing in 300- 375 litres of water for one hectare.

Spray herbicides at proper time in proper quantity with appropriate spray technique.

Rotate herbicides every year for better result.

In crop rotations use forage crops such as berseem and oat for weed management.

Use flat fan nozzle for spray.

In case of resistance in *Phalaris minor* against Isoproturan use Pinoxaden (Axial) or Pendimethalin (Stomp).

Precautions

Do not mix Pinoxaden with 2,4 D, spray 2,4 D one week after the spray of Penoxaden.

Do not use under/over dose of herbicide.

Do not allow the seed formation of weeds in fields.

Spraying should be done within 30-35 days after sowing.

Diseases and insect-pests Management

Loose and covered smut

Seed treatment with Vitavax/Bavistin @ 2g/kg seed for loose smut, and Vitavax & Thiram in the ratio of 1:1 or Tebuconazole 1.5 g/kg seed for covered smut should be used. Seed can be given solar treatment during the month of May -June. Soak the seed for four hours in water and keep it in sunshine for 10-12 hours. Afterwards, store the seeds in a dry place. In the field, collect the smutted earheads and burn them outside the field.

Rust

Rusts are multiple cycle diseases and spread like a wild fire under favorable environments. Though chemicals are available, the control by sprays may not be cost effective. Frequent sprays may be needed at regular intervals, which is not feasible for low input crop like barley. The use of resistant varieties is highly recommended and a number of resistant/tolerant varieties are available such as DWRUB52, DWRB73, DWRUB64, DWRB91 and DWRB92. Spraying with Tilt 0.1% or Bayleton 0.1% or Folicur 0.1% (1 ml in 1 litre water) immediately after appearance of the disease should be done.

Leaf Blight

It is severe in areas where the day is warm and humid especially in north eastern parts. The source of inoculum is both soil and seed and therefore seed treatment with Vitavax and Spraying with Bayleton 0.1% or Tilt @ 0.1% or Folicur 0.1% (1 ml/litre of water) is recommended. Grow resistant/tolerant varieties such as DWRUB52, DWRB73, DWRUB64, RD 2552.

Aphid

Barley crop is affected by aphid which causes heavy loss to the crop as well as the grain quality in susceptible variety. Spraying with Imidacloprid @ 20 g ai/ ha or Clothianidin @ 15 g ai/ha in 1000 litres of water. In case of heavy incidence the second spray can be made at an interval of 15 days.

Molya disease

The CCN affected soils are common in sandy areas of north eastern Rajasthan and adjoining Haryana. This causes heavy losses in crop by drastically reducing

tillering and earhead formation. The use of resistant varieties like RD2052 and RD2035 and RD2592 should be encouraged for such areas.

Harvesting, threshing

Barley crop gets ready for harvest by the end of March to first fortnight of April. Since barley has shattering character, it should be harvested when it ripens to avoid breaking of spikes due to dryness. Barley grain absorbs water from the atmosphere and should be stored at an appropriate dry place to avoid storage pest losses. For industrial purpose, choose an appropriate variety, sow and harvest timely with proper management.

Seed Yield

When cultivation of high yielding varieties of barley is done with improved scientific methods, they produce about 30-35 quintals of grain and 40-45 quintals of straw per hectare.

Seed Processing

Debearding is primarily done in barley to remove the beard, or awn, from bearded varieties of barley. Debearding is a crucial pre cleaning step to prevent clogging of seed processing machines and better seed-sizing operations and seed flowability. Debearders are effectively used for seed lot containing large numbers of incompletely threshed seed heads (W. P. Feistritzer 1975).

Seed Storage

Safe seed storage always depends upon the temperature, relative humidity of storage environment and seed moisture content. It helps in increasing seed viability and decreases damage chances due to storage pests and fungal infestation (Sharma A. K and Sendhil Ramadas 2018). These pathogens produce metabolic heat by creating a 'hotspot' that allows for greater insect population growth. Fumigating with 650 ppm phosphine gas concentration of the storage atmosphere is optimum for controlling pest (Anonymous 2020b) Harvesting of barley crop can be done at a seed moisture around 14 to 15% and at

Table 10. Permitted Contaminants in Barley Seed Production Field.

Factor	Maximum permitted (%)	
	Foundation	Certified
Off- type	0.050	0.20
Inseparable other crop plants: oats, wheat, gram, triticale	0.010	0.050
Plants affected by seed borne diseases (e.g., Loose smut)	0.10	0.50

such moisture level the seed lots should not be sent to warehouse. The best practice is to dry seed lots mechanically or naturally to bring the moisture to safe limit that is 9-10%. Seeds need to be protected from rodent and bird infestation in the warehouse where it is to be stored until marketed. Seed treated with 75 % WP Thiram or Captan @ 70 g in 500 ml water per 100 kg seeds is necessary for safe seed storage.

Seed Certification

Seed certification aims at providing good quality seeds of a notified variety to farmers. Hence certification of seed is not only restricted to the harvested seed but it aims at control of seed production at field level as well as managing the land on which seed production will be taken up. It can be done by meeting the specific requirements of the crop (Section a). For the certification of seed following certain seed standards for maintaining quality is recommended (Section b)

Specific Requirements for certification

The maximum percentage of off-types plants, objectionable weed plants, plants affected by seed borne

Table 11. Minimum Seed Certification Standards.

Quality parameter	Foundation seed	Certified seed
Minimum Pure seed	98.0 %	98.0 %
Maximum Inert matter	2.0 %	2.0 %
Maximum Other crop seed	10/kg	20/kg
Maximum Other distinguishable varieties	10/kg	20/kg
Maximum Weed seed	10/kg	20/kg
Minimum Germination	85 %	85 %
Maximum Moisture Normal	12%	12%
Maximum Moisture Vapor Proof Container	8.0%	8.0%

diseases given in (Table 10 & 11) (Anonymous 2013).

Quality aspect of barley

Quality aspects of barley consist of two major parts:

Physical appearance and color of the grains

Barley grains consists of grains 15-20% husk. Because of husk, consumers do not like to eat barley as a food grain.

As animal feed too husked grain has poor market because of high crude fiber percentage (8-10%).

Hull-less amber colored barley types will be attractive for human consumption and as animal feed.

Chemical composition of grains

Barley is highly digestible because of negligible gluten content.

Uniform kernel size, free from insect or fungal infection and cuts is an important factor to the malting industry.

The preferred protein content >9% is not preferred for malting, high protein prolongs the time required for stepping and causes uneven germination produces malt with excessive enzyme activity, reduces the mellowness of malt.

Constraints in barley production

The major constraints responsible for stagnation in area and production are as follows:

Agro-Ecological Constraints

Photo sensitive barley varieties, normally carry vernal and photo period sensitivity traits which induce lateness

Higher temperatures are known to induce abnormalities. Floret number are reduced at higher temperature of 24 degree Celsius in comparison to 18 degree Celsius. Tillering is also affected by the day and

night regimes.

It is cultivated on poor and marginal soils with poor soil fertility.

Agronomical Constraints

Negligible coverage under improved varieties.

Limited use of cash inputs like fertilizers and plant protection measures.

Second preference to barley sowing compared to wheat.

Socio-Economic Constraints

Demand for barley is almost constant due to the biased policies towards the fine cereals (Rice, Wheat).

There is no incentives whatsoever for the farmers to raise barley production.

Change in to lifestyle of population. People turned to fine cereals.

CONCLUSION

Climate-smart barley seed production combines the use of quality seed and suitable varieties with efficient water and nutrient management, conservation practices, integrated pest management, and proper seed processing and storage. Together, these practices help maintain seed quality and genetic purity while improving resource-use efficiency, productivity, and resilience. Adopting such approaches can make barley production more sustainable and better suited to changing climatic conditions, thereby supporting long-term food and nutritional security.

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