# Advances In Crop Improvement And Production Of White Onion Including Artificial Intelligence: A Review

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**Abstract** - India ranks second-largest producer of onion in the world followed by China. Onion are commercially grown and consumed extensively as both vegetable and spice across India. Among the different skin colors of onion, white onion holds significant agricultural importance globally due to its versatile culinary applications and economic values. Crop improvement is essential to meet domestic demands and fulfill export requirements of white onion. In recent years, the integration of artificial intelligence (AI) technologies revolutionized various aspects of crop improvement and production. This review paper highlights about recent advances in the application of AI techniques such as machine learning, deep learning and data analytics enhance the quality, yield and sustainability of white onion. The key areas of focus include genetic improvement, precision farming, crop management, quality control, predictive modeling and sustainability.

**Index Terms** – White Onion, Crop improvement, Production, Artificial intelligence.

## 1. Introduction

Onion (*Allium cepa* L.) is a significant biennial bulbous vegetable crop, part of the *Alliaceae* family within the order Asparagales. It is primarily cultivated for both local consumption and for export purposes. It is known by various vernacular names such as *Pyaz* in Hindi, Ullagaddi/Eerulli in Kannada and Venkayam in Tamil. It is one of the important commercial vegetable crop grown widely in different parts of the world. It is used as salad, pickles, for garnishing cooked food, fried, boiled and baked curries.

Dietary demand of onion is increasing day by day due to its nutritional, medicinal properties and it forms an essential part of our daily diet. Hence, there is greater demand for the produce throughout the year. It serves as an essential ingredient in every kitchen item as a vegetable and spice, by enhancing the flavour of numerous dishes. Hence, it is commonly referred to as the *'Queen of the Kitchen'*. In India, it is it is cultivated in an area of 1.43 million hectares, producing 26.09 million tonnes with a productivity of 18.23 tonnes per hectare (Anon., 2021). Though onion production in India has increased over the last two decades, the country needs to produce 33.39 million tons of onion by the end of 2050 based on current consumption (6.70 kg per capita), processing (6.70 %), export (9.00 %) and losses (20.00 %). In India, it is commercially grown in all over the states except Kerala and North Eastern states. The major onion growing states are Maharashtra, Madhya Pradesh, Karnataka, Rajasthan, Bihar and Odisha. The Karnataka state occupies second position in area (2.49 lakh hectare) and third in production (20.49 lakh tonnes) (Anon., 2022).

White onion is a variant of dry onion distinguished by its pure white skin and the presence of sweet, mild white flesh. It contains approximately 42 calories, 1.3 g of protein, 1.2 g of fiber and 100 g of vitamin C, serve as antioxidants (Singh *et al*., 2004). For processing of white onion, the dehydration industry specifically needs white onion varieties with a globe-shaped bulb and high total soluble solids (TSS) exceeding 18 $^{0}$B**.** However, Indian white onion genotypes typically exhibit TSS levels ranging from 11 to 13 $^{0}$brix (Kurade and Mathias, 1972). Meanwhile, sulfur compounds contribute to the distinctive odour and flavor of onions while also acting as active antimicrobial agents, there by supporting immune health (Griffiths *et al*., 2002).

## 2. Crop improvement

### 2.1. Breeding objectives

- Achieving high yields and High-Yielding Varieties (HYVs) capable of producing abundant seed yield.
- Enhancing bulb quality traits including size, shape, colour, pungency, firmness and dormancy. High Total Soluble Solids (TSS) content is crucial for meeting the demands of the dehydration industry, along with skin retention and elevated dry matter.
- Instilling resistance against various diseases such as purple blotch, basal rot, stemphyllium blight, anthracnose, pink root and bacterial rot.
- Developing resistance to insect pests, particularly thrips.
- Establishing resilience against abiotic stresses such as moisture stress, high temperatures, salinity and alkalinity.
- Development of varieties suitable for the export market.

### 2.2. Breeding approaches

#### 2.2.1. Introduction

It is an age-old approach to crop enhancement, entailing the introduction of crop plants or varieties to novel territories.

- The White Spanish variety, originating from Spain, ideal for cultivation in hilly regions. Additionally, the Early Supreme White, imported from America, thrives in short-day conditions.

#### 2.2.2. Evaluation

Germplasm is gathered and assessed to pinpoint genotypes possessing desirable traits. The cross-pollination nature of onions showcases extensive genetic diversity, providing ample opportunities to identify suitable types for specific regions through evaluation.

An experiment was conducted to assess various white onion genotypes for their growth, yield and related characteristics. The results revealed that Arka Swadista exhibited the tallest plant height (74.6 cm) and longest leaf length (66.83 cm). Meanwhile, ON-14-09 and GJWO-3 demonstrated superior performance, yielding the highest bulb yield per plot at 13.25 and 11.82 kg, respectively, along with the highest average bulb weight of 113.40 g and 105.55 g, respectively. Furthermore, ON-14-09 and GJWO-3 showcased the highest ten-bulb weight, measuring 968.75 g and 902.45 g, respectively. Bhima Safeda and Pusa White Round displayed the greatest polar diameter at 6.91 cm and 6.61 cm, respectively, while ON-14-09 exhibited the highest equatorial diameter at 7.36 cm (Amarananjundeswara *et al*., 2020).

The research compared morphological and physico-chemical properties of three white onion cultivars (Alibag, Sindhudurg Local and Phule Safed) grown in Roha. The Alibag variety showed superiority in various parameters including plant height, neck thickness, maturity duration, higher sweetness, lower pyruvic acid and sulphur. Phule Safed had the highest yield per plot and mineral content. Overall, Alibag variety is found well-suited to Roha's conditions and has potential role for geographical indication, enhancing market value due to its unique taste and medicinal properties (Shivani, 2020).

#### 2.2.3. Population Improvement

Due to its cross-pollination nature, onions consistently offer opportunities for employing novel population improvement methods, giving opportunities in creation of natural variability. A significant amount of variability is harnessed in onion breeding through diverse approaches. Different gene actions and combinations identified through genetic studies to generate new varieties and materials for hybrid development. Understanding the nature and extent of genetic variability, as well as the transmission of traits are crucial for enhancing selection efficiency. It is anticipated that demand for new open-pollinated varieties will persist in countries where growers are unable to afford the high cost of F1 hybrid seeds (Brewster, 2008).

**Table 1: Details of onion varieties released in India using population improvement methods**

| Variety released | Improvement method | Institute |
|---|---|---|
| Pusa White Flat | Mass Selection (Local collection) | IARI, New Delhi, 1975 |
| Pusa White Round | Mass Selection (Local collection) | IARI, New Delhi,1975 |
| Bhima Shweta | Mass selection for rabi season | ICAR-DOGR, Pune |
| Bhima Shubra | Mass selection for kharif& late kharif season | ICAR-DOGR, Pune |
| Arka Swadista | Fermented or bottle preservation | IIHR, Bengaluru, 2010 |
| Akola Safed | Field tolerant to pest and disease | Dr. PDKV, Akola, 2005 |
| Bhima Safed | Tolerate to thrips and diseases | ICAR-DOGR, Pune 2014 |

### 2.2.4. Breeding for seasonal adaptability

Due to delayed or erratic monsoon, farmers are now shifting towards late *kharif* planting. Irrigation facilities available from September to February supports for this transition. Late *Kharif* onions are planted between September and October and harvested in January-February aid in maturity, benefiting from the available 11-11.5 hours of day light. While, they yield large bulbs, they are prone to bolting and twins, reducing marketability. Varieties such as Bhima Shubra are recommended for late *kharif* cultivation due to their suitability (Lawande *et al*., 2009).

During the winter (*Rabi*) season, there's a growing demand for white onion varieties. Breeding programs aims to develop white onions with excellent storage capabilities. In this direction, DOGR recommended variety like Bhima Shweta to address this demand. In hilly regions such as Uttar Pradesh and Himachal Pradesh, winter crops are planted from October to November and harvested from June to July, while summer crops are planted from February to March and harvested from August to October. Although some Granex types exist, more varieties suited for long-day conditions are needed (Pathak *et al*., 2016).

### 2.2.5. Breeding for processing qualities

Onion processing industries globally aim to stabilize domestic market prices by producing dehydrated products and processed onions. Preferred varieties for dehydration are white, globose, pungent and high-yielding with disease resistance. Indian onion varieties typically have low total soluble solids (TSS) levels (11-13 %), but efforts have been made to develop varieties with higher TSS content. Punjab-48 (13.4 %), S-74 (14.3 %) and Texas Yellow (15.8 %) are recognized for their high TSS and suitability for processing (Raina *et al*., 1988). Roopali was better-suited both for storage and dehydration (Mahajan and Gupta, 2015). Jain Food Park Industries introduced White Creole, leading to the development of V-12 variety with TSS ranging from 15-18 % (Verma *et al*., 1999).

**Table 2: Performance of white onion varieties developed in India**

| Name of Variety | TSS % | Average yield q/ha |
|---|---|---|
| Pusa White Round | 11.13 | 300 – 325 |
| Pusa White Flat | 10.00 | 325 – 350 |
| Udaipur 102 | 10.06 | 300 – 350 |
| Agrifound White | 10.76 | 200 – 250 |
| Phule Safed | 10.13 | 250 – 300 |
| Punjab 48 | 11.00 | 300 - 325 |
| Bhima Shubra | 11.00 | 180 – 200 in kharif & 350 – 400 in late kharif |
| Bhima Shweta | 11.50 | 180 – 200 in kharif & 260 – 300 in rabi |

Rao *et al*., 2015

### 2.2.6. Molecular markers in onion

Different varieties of onion had their DNA digested using the Taq1 restriction enzyme, followed by ligation of adapters to the digested DNA. Through this process, the Sequence-Specific Amplification Polymorphism (SSAP) technique was able to identify approximately 300 polymorphic loci per primer set (Chaurasia *et al*., 2010). Varieties exhibited a range of similarities, spanning from 0.08 to 0.63. Notably, the highest similarity was observed between Pusa White Flat and Agri Found Light Red, while the lowest similarity was found between Pusa White Flat and Cadillac. The marker employed demonstrated a high capacity for detecting polymorphism among the varieties (Anandhan *et al*., 2016).

A study was conducted by Singh *et al.* (2021) to identify and characterize white onion genotypes with high total soluble solid (TSS) content using molecular markers. Analysis of TSS and DNA genotype data revealed that Bhima shweta (LTSS-12.09 %) and WHT-12L-HT-15-Reject-M-7 (HTSS-18.02 %) exhibit greater diversity compared to other genotypes. Additionally, other white onion lines, including WHTB-7G-GT-15-SC-M-7 (HTSS 18.80 %), WHT-2B-GT-18-SC-M-7 (HTSS 18.51 %), WHTS-4D-GT-18-MC-M-7 (HTSS 18.49 %), WHTB-3C-GT-18-MC-M-7 (HTSS 18.27 %) and WHTS-11K-Pickle-SC-M-7 (HTSS 17.68 %), were identified as superior in terms of HTSS content.

## 3. Production technology

### 3.1. Soil type, climate and seed rate

Onions thrive in soil types such as light loam, sandy loam or clay loam, preferably rich in organic matter and well-drained. The ideal soil pH ranges from 5.8 to 6.5. Broadcasting requires a seed rate of 20-25 kg per hectare. Transplanting necessitates 8-10 kg per hectare for *Rabi* season and 12-15 kg per hectare for *Kharif* season. Onions thrive in temperate climates, favoring moderate conditions without extreme heat, cold or excessive rainfall. For vegetative growth, temperatures ranging from 12.8 to 23 °C are optimal, while bulb formation occurs best within the range of 20 to 25 °C.

Dhar *et al.* (2019) studied effect of transplanting dates on growth and yield attributes of onion var. Bhima Shweta.The maximum plant height was observed on 15$^{th}$ September transplanting date which was significantly superior to other planting dates. Whereas the shortest plant height was recorded on 1$^{st}$ August transplanting date. Exposure of late transplanted plants to more congenial weather than that of early transplanted plants was helpful for better growth and development of onion plants. Also observed significant effect of planting date on plant height. Highest significant plant height was noted in Bhima Shweta.

Mahajan *et al.* (2018) conducted an experiment on varietal improvement, out of 75 lines of white onion, 8 lines (W-448, W-009, W-355, W-404, W-367, W-172, W-418, W-056) were identified as suitable for cultivation across all three seasons *viz*., *Kharif* (May-October), late *Kharif* (August - February) and *Rabi* (October

- April). These varieties exhibit adaptability to varying sunshine hours ranging from 2.48 to 9.66 hrs, with monthly average temperatures spanning from 10.51 to 36.34 ºC, and rainfall levels ranging from 0 to 273.71 mm.

### 3.2. Nursery raising

The land should be fertile and have good drainage. Raised beds should not exceed a width of 90 cm. Seed treatment involves using Captan and Thiram at a rate of 2 g per kg of seed. Seedlings are ready for transplanting after 6-7 weeks during the *Kharif* season and after 8-9 weeks during the *Rabi* season. Ideal seedlings measure 15-20 cm in height and 0.8-0.9 cm in thickness.

### 3.3. Irrigation

The initial irrigation should be given immediately after transplanting. Subsequent irrigation scheduling depends on factors such as soil type, crop stage and the prevailing season. Critical stages for irrigation management include bulb initiation and enlargement.

Study was conducted to know the effect of pulse irrigation (drip) on growth and yield parameters of white onion. The results showed that the seasonal water applied to white onion, using pulse irrigation (drip), varied between 274.46 mm for the $I_1$ treatment (0.8 ETC) and 408.46 mm for the $I_3$ treatment (1.2 ETC). The interaction analysis indicated that the highest values for polar diameter (63.88 mm), geometric mean diameter (59.51 mm), equatorial diameter (63.16 mm), average bulb weight (112.05 g) and yield (38.52 t/ha) were observed in the $I_2P_4$ treatment combination, followed by $I_3P_4$. Additionally, the highest average water use efficiency was recorded for the $I_1P_4$ treatment combination at 11.93 q/ha/cm (Madane *et al*., 2018).

### 3.4. Planting methods

a) **Broadcasting:** 20-25 kg seeds per hectare is required for broadcasting. A light irrigation is given immediately after sowing (thinned is done after 6-8 weeks).

b) **Drill sowing:** It is commonly fallowed in rainfed areas. Different methods of drill sowing are line sowing, criss cross sowing and two-way sowing.

c) **Transplanting of seedlings:** Transplanting is more commonly practiced under irrigated conditions. Spacing 15cm x 8-10 cm is fallowed.

d) **Planting of bulbs**: To meet out the demand of green onions. Bulbs are dibbled at 15 cm x 45 cm distance. For planting a hectare area, about 7.5 quintal of medium sized bulbs is required.

## 4. Artificial intelligence (AI)

The term Artificial Intelligence was coined by John Mc Carthy in 1955. Artificial intelligence (AI) refers to the simulation of human intelligence in machines that are programmed to think, learn and act like humans.

Paymode *et al*. (2021) introduced a pioneering approach to enhance onion crop management through the utilization of deep learning, specifically a Convolutional Neural Network (CNN) architecture. This CNN model was meticulously developed, trained and evaluated using extensive onion image data sets. Remarkably, the model achieved exceptional accuracy metrics, boasting 97.59 % accuracy on the training dataset and 92.45 % on the testing data set. The innovative model accurately identifies onion quality, distinguishing between healthy and defective onions. By sorting and grading onions based on their quality, this model has the potential to boost onion production within the country, thus supporting increased yields.

Zaki *et al*. (2021) introduced a cutting-edge technique for the detection of onion disease, specifically focusing on purple blotch, using a deep Convolutional Neural Network (CNN). This model identifies the distinctive abnormalities associated with the disease from images, achieving an impressive classification accuracy of 85.47 %. The study presents a pioneering method for swiftly and accurately diagnosing plant/crop diseases, thus establishing a solid theoretical basis for the integration of deep learning in agricultural practices.

Onion price prediction based on artificial intelligence experiment conducted by Nalini *et al.* (2020). Advancements in onion yield analysis focus on data mining. Predicting yield is vital in agriculture, involving factors like location, soil pH and nutrient levels. Third-party apps provide weather data, soil type and composition. The AI algorithms are trained using this data to create accurate yield prediction models. The system offers farmers precise fertilizer recommendations based on atmospheric and soil conditions, aiming to boost crop yield and farmer income.

## 5. Conclusion

Onion is a versatile crop with a long history of domestication and use, different institutes involved in crop improvement and production aspects have developed high yielding varieties, hybrids and standardized the management aspects of irrigation nutrients, weeds and diseases etc. Also developed storage structures, grading machines and artificial intelligence in onion. All these studies helping farmers to produce onion to meet out the internal requirements as well as export.

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