REVIEW ARTICLE Agricultural Reviews, Volume 45 Issue 4: 653-660 (December 2024)

Kharif Onion Production in India- Present Status and Future Potential: A Review

Deepa Sharma[1], Aanchal Chauhan[2]

10.18805/ag.R-2455

ABSTRACT

Onion is one of the most important commercial crops in India which is used as a vegetable, spice and rich in medicinal properties. In India major onion producing states are Maharashtra, Karnataka, Madhya Pradesh, Gujrat, Bihar, Andhra Pradesh and Rajasthan. In South India onion is cultivated three times in a year as *rabi, kharif* and late *kharif* crop whereas, in North India it is generally cultivated as *rabi* crop. Major portion (60%) of onion produce comes from *rabi* season while *kharif* and late *kharif* crops contributes to a little extent (40%) in some parts of country. Maharashtra, Gujarat, Karnataka and Rajasthan are major *kharif* onion producing states. *Rabi* onion is generally harvested in April-May whereas *kharif* onion and late *kharif* is harvested in the month of October-November and January-February, respectively. Major portion of *rabi* season produce is stored upto October month for domestic consumption. There is a critical gap in supply of onion from the months of October to December. Therefore, *kharif* onion plays an important role not only in fulfilling consumers demand but also in controlling market price of onion. So far *kharif* onion production in India is limited to three four states only and it should be prioritized in other states too by keeping in view its importance. Various research perspectives, challenges and management strategies involved in *kharif* onion production has been reviewed in this article.

Key words: Challenges, *Kharif* onion, Management strategies, Production, Perspectives.

Onion is the most important vegetable crop among various *Alliums* grown in India. It is used in every household every day in vegetables, soups and curries. Onion possesses rich medicinal values and used for preparation of various homeopathic, unani and ayurvedic medicines. It shows strong anti-platelet and blood thinning activities in human blood, protect against arteriosclerosis, cardiovascular disease, stroke, diabetes, osteoporosis and heart attack (Augusti, 1990). China and India are the primary onion growing countries, followed by the USA, Egypt, Iran, Turkey, Pakistan, Brazil, the Russian Federation and the Republic of Korea (FAO, 2012). In India, onion is predominantly cultivated during *rabi* about 60% followed by 20% each in *kharif* and late *kharif* season (Tripathy *et al*., 2014). In India area under onion cultivation is 12, 93,000 ha with a total production of 2, 17, 18, 000MT and an average yield of 16.8 MT/ha (NHB, 2019). Maharashtra is leading state whereas productivity is highest in Gujarat. There has been a steady increase in area and production of onions in the last few decades. *Kharif* crop is grown on almost one lakh hectare area in India. Main *kharif* onion producing states are Karnataka, Andhra Pradesh, Rajasthan, Tamil Nadu and Maharashtra.

In India main onion produce comes from *rabi* season crop, some of which is exported and rest is stored for domestic consumption. The stored onion gets exhausted by August- September and people of India face onion crises every year from October to March till fresh produce comes to the market (Sharma and Dogra, 2017). However some states like Maharashtra, Karnataka and Madhya Pradesh are producing *kharif* onion. The *kharif* produce from these states calms down the consumers' needs to some extent but is not sufficient to be supplied in whole country and we have to import onion from other countries due to which prices goes very high. Apart from this late monsoon, heavy rainfall during crop growth season in these states results in heavy crop losses in *kharif* onion (Sharma, 2009; Mohanta *et al*., 2017). In addition to these problems, unavailability of seeds of high yielding varieties in *kharif* season also leads to non-acceptance of *kharif* onion production by the farmers (Hiraveet *et al*., 2015). However by using scientific techniques like use of high yielding varieties, planting on raised beds, sets planting, making channels to drain irrigation water, using weedicides to control weeds, taking proper plant protection measures farmers can successfully raise *kharif* onion (Yoo *et al*., 2019; Tripathi and Lawande, 2015; Kandil *et al*., 2013 and Lawande *et al*., 2011). *Kharif* onion production is important in stabilizing onion prices as well as it ensures round the year supply to the consumers (Abd El-All *et al*.,

[1]College of Horticulture and Forestry, Dr. Y S Parmar University of Horticulture and Forestry, Neri, Hamirpur-177 001, Himachal Pradesh, India.
[2]College of Horticulture and Forestry, Dr. Y S Parmar University of Horticulture and Forestry, Thunag-175 048, Mandi, Himachal Pradesh, India.

Corresponding Author: Deepa Sharma, College of Horticulture and Forestry, Dr. Y S Parmar University of Horticulture and Forestry, Neri, Hamirpur-177 001, Himachal Pradesh, India.
Email: deepabanyal@gmail.com

How to cite this article: Sharma, D. and Chauhan, A. (2024). *Kharif* Onion Production in India- Present Status and Future Potential: A Review. Agricultural Reviews. 45(4): 653-660. doi: 10.18805/ag.R-2455.

Submitted: 28-12-2021 **Accepted:** 20-07-2022 **Online:** 30-07-2022

2012; Sharma and Jarial, 2017). *Kharif* onion prices are high as compared to *rabi* crop and hence farmers can earn more benefits by its cultivation (Tripathy *et al*. 2014). Most of the farmers are ignorant about the *kharif* onion production and therefore this technique should be deliberately popularized among the farming community. More emphasis is needed towards varietal development and seed production. Salient research work done by many institutes and researchers in this direction is being reviewed here in this article.

Potential

Kharif crop (rainy season) is now being adopted by many farmers in the north and eastern parts of the country which has revolutionized the onion production and marketing in the country. *Kharif* season produce can bridge the gap between demand and supply of onion during lean period (October-March) in our country. Besides price stabilization onion production in *kharif* season (Pandita, 1994) offers a good alternative to the farmers for obtaining higher returns. It can help in foreign exchange earnings by increasing the export of onion from main crop (*rabi*) most of which is generally utilized for domestic consumption. Maharashtra, Karnataka and Madhya Pradesh are major *kharif* onion producing states in India. In India, Maharashtra is main kharif onion producer and three crops are taken here in a year *i.e.*, in *kharif* season 10-15 per cent, in late *Kharif* 20-40 per cent and in *Rabi* season 50-60 per cent. Maharashtra leads in *kharif* onion cultivation due to availability of extreme short-day cultivars (*viz.*, N-53, B-780, Phule Samarth, Agri Found Dark Red and local strains) and favorable climatic conditions. To make onion available throughout the year in India *kharif* onion production by farmers need to be prioritized (Sharma and Jarial, 2017). For this main focus should be given on development of new varieties with high yield, diseases and pest resistance, low splitting and bolting and having long shelf life. Nursery production of *kharif* onion crop is also a major problem due to scorching sun in May-June. Therefore, improved techniques for nursery production and use of sets for crop planting should be adopted. *Kharif* onion production possesses a huge potential in terms of increased profits to the farmers as well as uplifting of society. Therefore, it should be popularized among farmers of every state so that area and production under *kharif* onion can be increased.

Challenges and bottlenecks

Kharif crop of onion is often affected severely by cloudy atmosphere, late rains and incidence of various pests and diseases. Therefore, at present its cultivation is restricted to certain area with low yield potential and poor keeping quality. Successful nursery production during summer season is the main problem for growing of *kharif* season crop. However, to avoid these problems, *kharif* onion crop can be raised successfully through onion sets. Sets are small onion bulblets which are harvested before scorching summer prevails and then stored for replanting in *kharif* season. Seed rate, set planting time and sets size (Mohanta *et al*. 2017) are the most important factors which may influence the growth and yield of onion bulbs. It is important to increase the yields for enhancing the export level, so that it helps in foreign exchange earning to the country. The present review article is therefore written to provide information about the current status of research and development on *kharif* onion. The production of *kharif* onion is very low due to erratic monsoon, cloudy weather, constant drizzling during crop growth period. These climatic conditions aggravate many foliar as well as soil born diseases. The occurrence of weeds during rainy season is also very high. All these factors leads to yield losses and productivity of *kharif* onion is not more than 10 t/ha. In India various research institutes like DOGR, Rajgurunagar, Pune, NHRDF, Nasik, IIHR, Bangluru, IARI, New Delhi and many State Agricultural Universities (SAU's) are working on these constrains and developing technologies to enhance *kharif* onion production. National Research Centre for Onion and Garlic demonstrated that *kharif* onion productivity can be enhanced from 10 to 25 t/ha (Tripathi and Lawande, 2015).

Problems faced in *kharif* onion production are

- Lack of standardized/ recommended varieties for specific agro-ecological situations.
- Lack or unavailability of planting material (seed or sets) in time.
- Water stress/high temperature during the time of seedling /nursery production.
- High disease incidence during monsoon.
- Problems in curing and drying of onions after harvest.
- Low shelf life due to sprouting in storage.
- Severe weed problem in rainy season.
- Lack of fertilization/ fertigation schedule.
- Lack of awareness among farmer.

For getting benefit of high prices farmers need to enhance their productivity. Poor yield, more disease and pest incidence, weeds and poor storage life due to more moisture content in bulbs are major problems in *kharif* onion production. Due to these lacunas farmers prefer to grow *rabi* crop and avoid *kharif* onion production. Efforts have been made to solve these problems by various research organizations in the past. Therefore, standardization of *kharif* onion cultivars, raising healthy nursery or sets, plant protection, growth regulation and curing, chemical treatments for prevention of post-harvest losses are some important aspects towards the successful cultivation of *kharif* onion.

Advances in production technology

Standardization of suitable variety

The productivity of *kharif* onion is far behind as compared to *rabi* crop. The higher productivity could be achieved by selection of suitable varieties, balanced nutrition, optimum water management as well as need based plant protection measures. Among all these factors, selection of suitable varieties plays an important role in enhancing the yield as well as productivity. To have continuous supply of onion

round adoption of *kharif* and late *kharif* onion production is of utmost importance. While going for kharif onion production selection of appropriate variety is a basic step towards its success. Keeping this in view, many researchers from India are working on standardization of some improved varieties and advanced lines of common onion (*Allium cepa* L.) for cultivation in *kharif* season. For *kharif* onion production cultivars having early maturity, free from early bolting, longer storage life and high yields are desirable. In addition, ideal *kharif* variety should have early bulbing, high photosynthetic efficiency, thin neck and resistance to diseases and tolerant to water stagnation. It was found that N-53, Baswant–780, Agrifound Dark Red, Arka Kalyan perform good for *kharif* season (Tripathiand Lawande, 2015).

Twelve varieties of onion were evaluated by Mohanty *et al*. (2000) during the *kharif* season and they reported highest bulb yield of 315.2 q/ha from variety Agrifound Dark Red which was statistically *at par* with N-53 (302.5 q/ha). Agrifound Light Red and Arka Niketan had shown better keeping quality among the tested varieties. Mohantyand Prusti (2001) evaluated twelve varieties of onion during kharif season and recorded highest yield in variety Arka Kalyan (21.06 t/ha) which was at par with Arka Niketan (19.64 t/ha) and Pusa Madhavi (18.96 t/ha). Arka Niketan and Pusa Madhavi produced medium bulb with better storage quality. Onion varieties Agri found Light Red and N-53 had performed best during *kharif* season (Mohanty, 2002) with highest bulb yield. On the basis of performance of five onion cultivars during kharif season Sarkar and Jain (2002) observed highest bulb yield in variety Agrifound Dark Red (174.39 q/ha) whereas, maximum plant heightand number of leaves per plant, bulb diameterand TSS was found in variety Arka Niketan. Agrifound Dark Red and Arka Niketan with better keeping quality, medium bulb and moderately high yield was suggested (Mohanty *et al*., 2003) as a substitute to N-53 and Arka Kalyan for commercial cultivation in the rainy season. The cultivar Bhima Red and Bhima Raj performed well for the Akola region in *kharif* season as reported by Hirave *et al*. (2015). Sharma (2009) tested onion varieties bred by different institutes for their performance in the low hills of Himachal Pradesh and revealed that Baswant-780 was the top yielder with a mean bulb production of 230.50 q/ha. As reported by Sharma and Jarial (2017) Agrifound Dark Red was found to be the best suited cultivar for kharif onion production in lower hills of Himachal Pradesh. Sharma and Dogra (2017) evaluated four varieties of onion in *kharif* season which were planted on five dates separated at 10 days intervals starting from 15th July to 25th August and they observed highest bulb yield in variety Agrifound Dark Red transplanted on 15th August.

Another important point to be considered while selecting a good variety is ratio of bolting and doubling in a variety. Bolting and doubling may be due to higher temperature prevalence throughout the crop period, smallest bulb size, varietal character and late transplanting. Both of these are considered as negative parameter with respect to onion bulb production as they reduce the marketable yield. Hirave *et al*. (2015) observed zero bolting percentage and minimum splitting percentage in variety Bhima Red. Bhima Red had shown 0.33% splitting of bulb which was found to be at par with variety Bhima Raj (0.67%), Agrifound Dark Red (1.00%), Bhima Super (1.33%) and Baswant-780 (1.67%). Whereas, maximum splitting percentage (2.67%) of bulbs was reported from variety Phule Samarth. Similar observations were also recorded by Jadhav *et al*. (1990). Khar *et al*. (2007) evaluated ten promising lines of onion and reported that variety Baswant 780 performed well with less bolters and this variety found stable for this trait. The variations in the bulb yields of different varieties of onion have also been reported from several places (Patil *et al*., 1991; Bhonde *et al*., 1992; Khan, 1997; Mohanty and Prusty, 2002). Lawande *et al*. (2011); Lawande *et al*. (2011a) had reported superiority of Bhima Super and Bhima Red for *kharif* onion production. Recently Directorate of Onion and Garlic Research (DOGR) had recommended release of two varieties *i.e*. Bhima Super (red coloured bulbs) and Bhima Shubhra (white bulbs) for *kharif* season at national level.

Standardization of transplanting time and set size

The nursery for *kharif* onion is generally sown in April-May. At this time, it is very difficult to raise healthy seedlings due to scorching heat and lack of irrigation water in summer. Seedling transplanting coincides with onset of monsoon, heavy showers and water stagnation which leads to high seedling mortality. For obtaining healthy seedlings, seeds of selected varieties should be treated with captan or thiram or bavistin prior to sowing. The treated seeds should be sown in lines at 10-15 cm spacing on broad based furrow during first week of May. Drip or sprinkler irrigation saves upto 40-50% water and ensures 90 to 100 per cent seed germination with good seedling stand. Shading over nursery beds using 50% agri shade net or hessian cloth protects young seedlings from scorching sunlight and ensures rapid and higher seed germination. Shade net should be removed after 30-35 days after which seedlings get established properly to avoid etiolation and lanky growth (Tripathy and Lawande, 2015). Use of sets or bulblets is another method to avoid nursery production during harsh summer months. Planting *kharif* onion using sets is also helpful in getting early crop so as to meet the demand of green onion for salad in early winter. Sets of *kharif* onion using varieties like Agrifound Dark Red, Baswant 780, N-53 and Arka Kalyan can be raised from mid February to mid March. Raised beds of 3.0×1.0×0.15 m size are prepared. To cover one square meter area of the bed 15 g of seeds are sufficient. The plants are kept in the nursery bed itself up to April-May till they develop small bulblets called sets of 1.5-2.0 cm diameter. Harvesting is done along with the tops and sets are stored till July-August in a well-ventilated house. Such well stored sets are used for replanting in the *kharif* season. Medium sets of 1.5-2.0 cm diameter are ideal for *kharif* onion production as they do not bolt much and the proportion of

splitted bulbs and doubles was also found minimum in this category (Madisa, 1994; Ansari *et al*. 2009). Khokhar *et al*. (2002) observed highest percentage of bolting (31.1%), doubles (69.4%) and higher un-marketable bulb yield in kharif onion raised using large set sized sets. The tendency to develop double bulbs in large sized sets affects their consumable appeal as reported by Rabinowithch (1979); Khokhar *et al*. (2001). The planting time of *kharif* onion varies from place to place and it generally starts from first week of June to second week of August. Onion is photo-thermo sensitive crop and bulb production occurs in long photoperiods, but early cultivars react faster to a long photoperiod and leads to early bulbing with short bulbs without completing vegetative period. The interaction between temperature and photoperiod strongly affects bulb production as well as bolting in plants. The bulbing ratio increases with increasing temperature and photoperiod. It has been reported by Tarakanov and Alemzadeh (1997) that increase in photoperiod promoted bulbing, while under very short photoperiods (8 hours per day) no cultivars bulbed, even after 60 days of growth. Bulb maturity found to decrease linearly with increasing temperature and lengthening photoperiod. Low temperature and increased photoperiod (8-14 h d^{-1}) shortened the time to floral initiation as reported by Khokhar (2008). Set size used for replanting also affects the bulb production and bolting. In kharif onion production using sets the sets diameter is also a primary factor that affects bulb or flower stalk production. A large onion set produces flowering stalks more rapidly than a small one as reported by Heath and Mathur (1944). Yamaguchi (1980) had also reported that the ideal size of a set should be 1.5-2.0 cm in diameter and bulbs greater than 2.5 cm in diameter are prone to vernalization and bolting at low temperature.

Time of planting *kharif* onion varies in different parts of the country. In Maharashtra planting is done July to August and in northern plains from mid or end of August whereas in West Bengal and Orissa late transplanting is done *i.e*. from August to September (Pandey, 1993). In Himachal Pradesh best time for *kharif* onion cultivation is from 25th July to 15th August as advocated by Sharma and Jarial (2017); Sharma and Dogra (2017); Sharma *et al*. (2009).Further delay in transplanting leads to a continuous decrease in plant height. Highest plant height (55.06 cm) was observed on 5th July transplanting, whereas the minimum plant height (47.64 cm) with transplanting on 25th August. This might be attributed to longer growth period of early planted crop before the initiation of bulb development (Sharma and Jarial, 2017). Significant effect of transplanting dates on plant height in *kharif* onion was also reported by Dev *et al*. (2005). Good production is often associated with good growth and development of any crop. The growth and yield of cultivated crops are influenced by genotype, growing environment and agronomic practices. Planting time is one of the important factors that greatly influence the growth, yield and quality of onion (Abd El-All *et al*. 2012; Kandil *et al*. 2013). Most of onion cultivars are sensitive to photoperiod and their range of adaption is limited. Kharif onion is an off-season cultivation of the crop for which standardization of varieties is of immense utility (Hirave *et al*., 2015). Thus, it is imperative to assess the stability inperformance of recommended varieties of onion for aspecific location, especially for kharif onion (Haldar *et al*., 2009). The conventional method of planting which farmers usually follow is to plant on flat bed or in ridges and furrows with surface irrigation. These methods do not provide efficient nutrient management and drainage which results more small size bulbs and higher disease incidence. Therefore crop should be planted on raised beds with drip or sprinkler irrigation resulted in higher yield of bigger bulbs than other methods (Tripathi and Lawande, 2015).

Irrigation and fertigation schedule

The nutrient management in kharif onion production is very important because the leaching and runoff losses of nutrient are high due to frequent rains. The recommended dose of fertilizers for *kharif* onion is 100 kg nitrogen, 50 kg phosphorus and 50 kg potassium per hectare. In addition to NPK fertilizers regular dose of 50 kg sulfur per hectare should also be applied. The half of nitrogen and full doses of phosphorus, potassium and sulfur should be applied before planting while the remaining 50% of nitrogen should be applied as topdressing during the growth period of the crop. If fertigation facility is available it should be given in ten split doses after every five days. The foliar application of nutrients containing water-soluble fertilizer and micronutrient mixture is also helpful. These should be applied between 45 to 75 days after transplanting. This helps in bulbs enlargement.

Weed management

Weed is a severe problem in growing *kharif* onion. Due to high temperature and humidity in rainy season rapid weed growth takes place and frequent removal is needed to save the crop. To control weeds in nursery use of stomp (Pendimethalin) @ 2 ml/litre of water after seed sowing checks weeds up to 30 days. It can also be used for direct seed sown crop. In case transplanted crop spray of weedicides like Goal @ 1.6 ml per litre or stomp @ 3.5ml per litre of water after trans planting of seedlings or just before transplanting of onion followed by immediate irrigation is effective. These effectively control weeds up to 30 to 35 days but after that hand weeding should be done. Two hand weedings effectively controlled the weed population in onion nursery of variety Agrifound Dark Red during *kharif* season, followed by combined application of pendimethalin @ 1.5 ml + quizalofop ethyl @ 0.75 ml/L before seed sowing and at 15 days after seed sowing (NHRDF, 2017-18).

Plant protection

In onion, purple blotch caused by fungus *Alternaria porii* is a major problem in almost all parts of the country (Kareem *et al*. 2011). It is more severe during *kharif* and late *kharif* season. Among the pests, thrips are most damaging insect affecting growth and yield of onion. The fungus required

moderate temperature (around 25°C) and high relative humidity (90% or higher) for sporulation. Symptoms include small white sunken spots on the leaves which enlarge, become eye shaped under moist conditions. Finally, these spots turn to purple coloured lesions surrounded by a broad chlorotic margin. Ultimately leaves dry up and drop after 2-3 weeks. Sprays of mancozeb or chlorothalonil @ 2.5 gm/l at 10 days intervals have been found effective in reducing the disease. Cultivars *i.e.* Bhima Kiran, Bhima Super, NRCRO-2 and Col-652 showed tolerance to both purple blotch as well as thrips (Kareem *et al*., 2011) infestation under *kharif* season. Anthracnose caused by *Colletotrichum gloeosporiodes (Glomerella cingulata)* is another serious disease occurring in *kharif* onion. During rainy season conidial movement with water is high which spread the disease to large area in short time. The symptoms appear as pale yellow water soaked spots on the leaf, which increase lengthwise covering the whole leaf. The affected leaves shrivel, droop down and finally wither. Since the pathogen survive on crop residue, sanitation and destruction of infected plant debris helps in reducing the disease. Proper drainage is essential for control of disease. Application of benomyl @ 0.2% as soil treatment, spray of mancozeb @ 0.25% carbendazim @ 0.1% and captafol (0.2%) gave good control of the disease. Thrips is most injurious insect pest of onion. The insect is very minute and yellow to dark brown in colour which sucks the sap of the leaves. The thrips infested leaves develop spotted appearance which turn pale white blotches.Incase of severe infestation leaves coiling and twisting occur and plant shows stunted growth. The yield loss may be upto 50-60%. The regular application of insecticides such as malathion @ 0.1% or metasystox @ 0.1% and cypermethrin @ 0.01% or deltamethrin 2.8% @ 20 ml a.i./ha control the insect. Since the control of thrips is difficult, thus an integrated approach is necessary for the effective control of this insect. Biological control using natural enemies, including predaceous mites, minute pirate bugs and lacewings feeding on thrips considerably lower their population. Avoid planting onions near cereal fields if possible, because thrips often increase in those fields in the spring and migrate to onion fields when the grain senesces, or when the alfalfa is cut. Overhead irrigation and rainfall also suppress the thrips numbers.

Harvesting and post-harvest management

The excessive vegetative growth is a big problem in *kharif* onion. The plant height sometime goes up to one meter and neck of plant becomes thick while the bulbs size remains small. This happens because of poor translocation of assimilates from leaves to bulbs. Storage is one of the most important aspects for post-harvest handling of onion. It is also very difficult to store kharif onion for a longer period due to its higher moisture content. Rotting, sprouting, physiological loss in weight and moisture evaporation results in serious losses up to 50-90 per cent depending upon genotype and storage conditions.

Pre-harvest sprays had been widely applied without impairing the keeping quality of onion. Application of growth substances and fungicides like ethrel, cycocel, carbendazim and aureofungin as pre-harvest foliar application have gained prominence. These compounds greatly enhance storage through inhibition of sprouting, rooting andreduction in the physiological loss in weight. Pre harvest sprays of 100 ppm salicylic acid or cycocel at the rate of 2,500 ppm in *kharif* onion considerably enhance the crop growth, yield and reduced various post harvest losses such as weight loss, loss in diameter, sprouting and rotting during storage (Sharma and Chauhan, 2021). Dwivedi *et al*. (2019) reported that pre harvest spray of GA_3 at the rate of 100 ppm reduce neck thickness and improves yield in *kharif* onion. Many researchers had used different chemicals to enhance the shelf life of onions and a few among them are abscisicacid (ABA), gibberellin (GA3), auxin and cytokinin (CK) (Abdel-Rahman and Isenberg, 1974), maleichydrazide (MH), cycocel (CCC) and ethrel (Misra and Pande, 1979), trakepho and ethrel (Pospisilova and Janyska, 1978), paraquat (Bubl *et al*. 1979) and wondalhid, ethrel, fruitone, offshoot and antack (Iordachescu and Mihailescu, 1981). Decreasing rotting percentage as compared to control was observed when onion crop sprayed with cycocel (lihocin) @ 2500 ppm on 75 and 90 days after transplanting (Anonymous, 2004). Application of micronutrients has been also found effective in enhancing storage life of onion. It was noticed that application of $CaCl_2$ (0.5%) at 60, 75 and 90 DAT performed better than all the treatments in terms of lowest total loss. Foliar application of boric acid (0.25%) at 30, 45 and 60 DAT performed better in terms of lowest physiological weight loss whereas foliar application of boric acid (0.25%), zinc sulphate (0.5%) and $CaCl_2$ (0.5%) at 60, 75 and 90 DAT showed lowest decay loss (NHRDF, 2017-18). Application of these synthetic growth regulators can alter the levels of the naturally occurring hormones, resulting in modification of growth and development in the desired direction and to the desired extent. Techniques like proper curing, neck cut and exposure of bulbs to gamma irradiation before storage are proved to be useful techniques in delaying sprouting and their subsequent deterioration resulting in improved shelf life (Anbukkarasi *et al*., 2013).

The *kharif* season crop matures in 90-105 days but neck fall do not occur and plant remains in active growth stage. The bending of neck of plants by rolling of empty barrel two or three days before harvesting found useful for increasing shelf life. The curing of *kharif* onion is important for better shelf life but high humidity and cloudy weather do not facilitate proper curing which results in more losses. Use of both end open plastic tunnels helps in increasing shelf life of kharif onion. Many workers has studied the effect of curing methods on storage behavior of onions and found that both field and artificial curing methods were effective in reducing physiological weight loss and rotting percentage than the non-cured bulbs. Field curing by windrow method for three to five days, shade curing with tops for 10 to 12 days and

2.5 cm neck length had shown minimum storage losses in onion, more number of scales and colour retention for longer period as reported by Singhal (2000). Satish and Rangann (2002) reported that artificial curing of onion bulbs for 10 to 14 hours at 45°C with air flow rate of 222 m^3 per minute had shown good results as compared to 8 to 10 days of sun curing. Some workers suggested bulb harvesting with leaf intact method to enhance storage life of onion (Nega *et al*. 2015). Kukanoor *et al*. (2006) suggested maximum physiological loss in bulb weight was noticed when bulbs were stored without leaves. This may be due to absence of foliage resulting in full exposure of the bulbs to the temperature leading to increased surface temperature and moisture reduction. However, Yoo *et al*. (2019) linked the presence of leaves after harvesting with increased pungency in onion bulbs. This may be due to translocationof flavor (sulfur) compounds from the leaves to the bulbs duringthe drying period after onion plants are pulled from the soil indicating that leaf cutting immediately after harvesting prevents increase in bulb pungency.

Another important technique to control losses due to sprouting in onion storage is use of gamma irradiation. Many researchers had done considerable work in this direction and they confirmed the sprout-inhibiting effect of gamma irradiation. Sawyer and Dallyn (1959) reported complete onion sprout suppression with 8000 r gamma irradiation treatment. The sprouting of onion bulbs was completely inhibited at 3000 r (Ogata *et al*., 1959). They also noticed that the Inner buds of onion bulbs which were compelled to inhibit the sprouting by the irradiation were browned and dead, but the injured parts did not extend to the outside of the buds. Furata *et al*. (1978) reported that gamma irradiation of onions at 5-200 Gy was more effective in sprout inhibition both at the high irradiation doses and at the high dose rates.

Studies focusing on evaluating the effect of ionizing radiation on onion sprout inhibition have been carried out since the fifties. Sawyer and Dallyn (1959) have reported the ability of low doses of gamma irradiation to inhibit sprout development during storage of onion. Thomas *et al*. (1975) reported for getting a complete inhibition of sprouting by irradiation at 6 to 9 krad during storage only if the bulbs were irradiated within a fortnight of harvest when they were in the dormant state.

Future potential

For the last few years, we are continuously observing shortage of onion from October to March months due to which price gets increased. To combat this issue our Government has to import onion from other countries during lean period which also adds to the increased cost. *Kharif* onion production in India is done in very small area. Though it is a very important option and needs to be popularized among farmers for wide adoption. This will help in price stabilization as well as fulfilling consumers demand throughout the year. Apart from this *kharif* onion production can provide chances to export more quantity of *rabi* produce in the international market.

CONCLUSION

There is need to increase *kharif* onion production for onion supply throughout the year with stabilized priced. There is critical need to develop varieties suitable for *kharif* season having more yield, disease and pest resistance, thin neck, low bolter and good storage quality. Use of improved cultivars, adoption of precision farming and innovative techniques to properly cure the bulbs and to increase post-harvest life can prove to be important steps in increasing *kharif* onion production. We should focus our research strategies in this direction. Although many institutes are efficiently working in this direction but a comprehensive approach in this regard is strongly needed.

ACKNOWLEDGEMENT

Authors gratefully acknowledge the Department of Science and Technology, Govt. of India, New Delhi for financial assistance in the form of DST sponsored project to popularize *kharif* onion production.

Conflict of interest

All authors declared that there is no conflict of interest.

REFERENCES

Abd El-All, H.M., Seham, M.A. and Sahim, S.M. (2012). Effect of planting dates on growth, yield and quality of some green onion (*Allium cepa* L.) cultivars for local marketing and exportation. Journal of Biological Chemistry and Environmental Sciences. 7(1): 33-47.

Abdel-Rahman, M. and Isenberg, F.M.R. (1974). The role of exogenous plant regulators in the dormancy of onion bulbs. Journal of Agricultural Science. 82: 113-116.

Anbukkarasi,V., Paramaguru, P., Pugalendhi, L., Ragupathi, N. and Jeyakumar, P. (2013). Studies on pre and post-harvest treatments for extending shelf life in onion- A review. Agricultural Reviews. 34(4): 256-268. doi: 10.5958/j.0976-0741.34.4.011.

Anonymous, (2004). Annual Reports. NHRDF, Nasik, Maharashrata.

Ansari, N.A., Jaime, A., Teixeira da Silva and Yazdani, N. (2009). Effect of onion set size and cultivar on production of green bunch onion (*Allium cepa*). Middle Eastern and Russian Journal of Plant Science and Biotechnology. 3 (Special Issue 1): 5-9.

Augusti, K.T. (1990). Therapeutic and medicinal values of onion and garlic. In: Onions and Allied Crops. 3: 93-108.

Bhonde, S.R., Srivastava, K.J., Singh, K. N. (1992). Evaluation of varieties for late *kharif* crop of onion in Nasik area. News Letter. 12(1): 1-2.

Brewster, J.L. (1997). Onions and Garlic. In: Wien HC (Ed), The Physiology of Vegetable Crops. CAB International, Wallingford, UK. pp 581-619.

Bubl, C.E., Richardson, O.G. and Mansour, N.S. (1979). Pre-harvest foliar desiccation and onion storage quality. Journal of the American Society for Horticultural Science. 104(6): 773-777.

Dev, H., Badiyala, S.D. and Kohli, U.K. (2005). Response of *kharif* onion (*Allium cepa* L.) to planting time and spacing in lower hills of Himachal Pradesh. Himachal Journal of Agricultural Research. 31(1): 61-64.

Dwivedi, B., Diwan, G. and Asati, K.P. (2019). Effect of Plant growth regulators and their methods of application on growth of *kharif* onion (*Allium cepa* L.) cv Agrifound Dark Red. International Journal of Current Microbiology and Applied Science. 8(9): 1597-1610.

FAO (2012). World Onion Production. Food and Agriculture Organization of the United Nations. http:// faostat.fao.org.

Furata, J., Raoka, E., Okamoto, S., FujisIro, H., Kanazawa, T., Ohnishi, T., Tsujh, Y., Hori, S. and Ojima, T. (1978). The gamma-ray dose rate effect in the sprout inhibition of onion and potato. Annu. Rept. Radiation Center, Osaka Prefect. 19: 69.

Haldar, A., Karak, C., Naik, A., Samanta, M. K. and Hazra, P. (2009). Identification of suitable early *rabi* onion varieties under West Bengal condition. Journal of Crop and Weed. 5(1): 124-129.

Heath, O.V.S. and Mathur, P.B. (1944). Studies in the physiology of the onion plant: II. Inflorescence initiation and development and other changes in the internal morphology of onion sets, as influenced by temperature and day length. Annals of Applied Biology. 31: 173-186.

Hirave, P. S., Wagh, A.P., Alekar, A.N. and Kharde, R.P. (2015). Performance of red onion varieties in *kharif* season under Akola conditions. Journal of Horticulture. 2. 2. DOI: 10.4172/2376 0354.1000132.

Iordachescu, C. and Mihailescu, N. (1981). Efficiency of some pre-harvest treatments on onion quality preservation. Acta Horticulturae. 116: 151-153.

Jadhav, R.S., Shinde, N.N., Sontakke, M.B., (1990). Performance of onion (*Allium cepa* L.) varieties in *rabi* season. Progressive Horticulture. 22: 84-86.

Kandil, A.A., Sharief, A.E., Fathalla, F.H., (2013). Effect of transplanting dates of some onion cultivars on vegetative growth, bulb yield and its quality. ESci Journal of Crop Production. 2(3):, 72-82.

Kareem, M.A., Krishna Murthy, K.V.M. and Nadaf, H.A. (2011). Study on etiology of the purple blotch disease of onion. International Journal of Plant Protection. 4(2): 419-420.

Khan, I. A. (1997). Performance of onion (*Allium cepa* L.) cultivars in mid hill conditions of Uttar Pradesh. Progressive Horticulture. 29(1-2): 97-99.

Khar, A., Devi, A.A., Mahajan, V. and Lawande, K.E. (2007). Stability analysis of some elite onion lines in late *kharif* season. Indian Journal of Horticulture. 64(4): 415-419.

Khokhar, K.M. (2008). Effect of temperature and photoperiod on the incidence of bulbing and bolting in seedlings of onion cultivars of diverse origin. The Journal of Horticultural Science and Biotechnology. 83: 488-496.

Khokhar, K.M., Hussain, S.I., Mahmood, T.H. and Bhatti, M.H. (2001). Effect of set size on bulb yield, maturity and bolting in local and exotic cultivars of onion during autumn season. Sarhad Journal of Agriculture. 17: 355-358.

Khokhar, K.M., Hussain, S.I., Mahmood, T.H. and Laghari, M.H. (2002). Bulb yield and quality as affected by set size in autumn season onion crop. Asian Journal of Plant Sciences. 1: 657-658. DOI: 10.3923/ajps.2002.657.65.

Kukanoor, L. and Basavarajan, Rokhade, A.K. (2006). Influence of curing methods on storability of onion. The Asian Journal of Horticulture. 2(4): 277-281.

Lawande, K. E., Mahajan, V., Krsihnaprasad, V.S.R. and Khar, A. (2011). Bhima Super-A New Red Onion Variety for *kharif* Season from DOGR. National Symposium on Alliums: Current Scenario and Emerging Trends., 12-14 March (p. 160), DOGR, Pune.

Lawande, K. E., Mahajan, V., Krsihnaprasad, V. S. R. and Khar, A. (2011a). Bhima Red and Bhima Raj- New Red Onion Variety for Different Season. National Symposium on Alliums: Current Scenario and Emerging Trends. 12-14 March, DOGR, Pune. (p. 161).

Madisa, M.E. (1994). The effect of planting date, set size and spacing on the yield of onion (*Allium cepa*) in Botswana. Acta Horticulturae. 358: 353-358. DOI: 10.17660/ActaHortic. 1994.358.58.

Misra, R.S. and Pande, S.C. (1979). Biochemical changes in onion bulbs during storage. The Punjab Horticultural Journal. XIX (1-2): 86-88.

Mohanta, S., Mandal, J. and Dhakre, D. S. (2017). Growth of *kharif* onion (*Allium cepa* L.) in response to planting dates and cultivars. Hort Flora Research Spectrum. 6(4): 262-267.

Mohanty, B.K. (2002). Studies on genetic variability, character association and path coefficients in *kharif* onion. Progressive Horticulture. 34(1): 60-64.

Mohanty, B. K. and Prusti, A.M. (2001). Performance of common onion varieties in *kharif* seasons. Journal of Tropical Agriculture. 39: 21-23.

Mohanty, B.K. and Prusty, A.M. (2002). Varietal performance of onion in rainy season. Indian Journal Agricultural Research. 36(3): 222-224.

Mohanty, B.K., Bastia, D.K., Prusty, A.M. and Mohanty, S.K. (2003). Performance of onion varieties in *kharif* season. PKV Research Journal. 25(1): 42-44.

Mohanty, B.K., Hossain, M.M. and Prusti, A.M. .(2000). Varietal assessment of common onion for horticultural traits during *kharif* season. Orissa Journal of Horticulture. (2): 8-11.

Naik, B.H. and Hosamani, R.M. (2003). Effect of spacing and nitrogen levels on growth and yield of *kharif* onion. Karnataka Journal of Agricultural Sciences. 27(2): 38-41.

Nega, G., Ali, M. and Menamo, T. (2015). Effect of curing and top removal time on quality and shelf life of onions (*Allium cepa* L.). International Journal Science Frontier Research. 5(8): 27-36.

NHB (2019). Indian Horticulture Database. National Horticulture Board, Ministry of Agriculture, Government of India, New Delhi.

NHRDF - Annual Report (2017-18). National Horticultural Research and Development Foundation, New Delhi.

Ogata, K., Iwata, T. and Chachin, K. (1959). The effect of gamma radiation on sprout prevention and its physiological mechanism in the potato tuber and the onion bulb. Bulletin of the Institute for Chemical Research, Kyoto University. 37(5-6): 425-436.

Pandey, U.B. (1993). Onions in India. Associated Agricultural Development Foundation. Bulletin no. 5 pp. 48.

Pandita, M.L. (1994). Status of *Allium* production and research in india. International Symposium on *Alliums* for the Tropics ISHS. Acta Horticulturae. 358: 79-86.

Patil, D.R., Hebbara, M. and Naganagoud, A. (1991). Performance of onion varieties on black soils. Karnataka Journal of Agricultural Sciences. 4(1-2): 54-56.

Pospisilova, J. and Janyska, A. (1978). Effect of chemical defoliants on onion quality. Rostlinnavyroba. 24(8): 879-888.

Rabinowithch, H.D. (1979). Doubling of onion bulbs as affected by size and planting date of sets. Annals of Applied Biology. 93: 63-66.

Sarkar, S.K. and Jain, B.P. (2002). Evaluation of onion varieties in *kharif* season. Indian Agriculturist. 46(1-2): 26-29.

Satish, S.V. and Ranganna, B. (2002). Development of hot air drying for bulk curing of onion. Mysore Journal of Agricultural Sciences. 36: 165- 170.

Sawyer, R.L. and Dallyn, S.L. (1959). Effect of gamma and fast electron irradiation on storage quality of onions. Proceedings of the American Society for Horticultural Science. 73: 390-397.

Sharma, A.K. (2009). Evaluation of onion varieties in *kharif* season under submontane low hill conditions of Himachal Pradesh. Annals of Horticulture. 2(2): 191-193.

Sharma, A.K., Bhatia, R.S. and Raina, R. (2009). Effect of planting dates, size of setts and methods of planting on *Kharif* onion (*Allium cepa* L.) under sub-mountain low hill conditions of Himachal Pradesh. Vegetable Science. 36(1): 74-76.

Sharma, D. and Chauhan, A. (2021). Effect of growth regulators on growth, yield and storage life of kharif onion (*Allium cepa*). Indian Journal of Agronomy. 66 (4): 483-487.

Sharma, D. and Dogra, B.S. (2017). Evaluation of *kharif* onion varieties and transplanting time for production under North-Western mid Himalayan region. Indian Journal of Horticulture. 74(3): 405-409.

Sharma, D. and Jarial, K. (2017). Effect of different varieties and planting time on *kharif* onion production in lower Shivalik hills of Himachal Pradesh. Current Agriculture Research Journal. 5(1): 74-80.

Singhal, S.C. (2000). Export of Onion - Challenges and strategies. Souvenir, National symposium on Onion and Garlic Production and Post-harvest Technology Management: Challenges and Strategies. National Research Centre for Onion and Garlic, Rajgurunagar, Nasik. pp 49-64.

Tarakanov, I.G. and Alemzadeh, A.N. (1997). Photoperiodic response in popular onion varieties grown in Iran. Journal of Isvestia TCXA. 1: 83-90.

Thomas, P., Srirangarajan, A.N. and Limaye, S.P. (1975). Studies on sprout inhibition of onions by gamma irradiation-I. Influence of time interval between harvest and irradiation, radiation dose and environmental conditions on sprouting. Radiation Botany. 15(3): 215-220. https://doi.org/10.1016/S0033-7560(75)80020-2.

Tripathi, P.C. and Lawande, K.E. (2015). Designing and evaluation of onion storage structures for Indian conditions. International Journal of Agricultural Science. 6(2): 918-24.

Tripathy, P., Sahoo, B.B., Priyadarshini, A., Das, S.K., Dash, D.K. (2014). Standardization of *kharif* onion cultivars. International Journal of Bio-resource and Stress Management. 5(2): 269-274. DOI: 10.5958/0976-4038.2014.00566.

Yamaguchi, M. (1980). World Vegetables, Principles, Production and Nutritive Values, University of California, Davis, California. pp 187-188.

Yoo, K.S., Daniel, L., Bhimanagouda, S.P., Eun, J.L. (2019). Effects of leaf cutting on bulb weight and pungency of short-day onions after lifting the plants. Scientia Horticulturae. 257: 108720.