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Organic basmati rice cultivation in India: Challenges from field to flight--A review article

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Abstract Basmati rice is the most popular aromatic rice variety known for its long, slender-grain type. India is the major producers and exporter of Basmati rice. It is the major rice variety in demand, two third of its production is exported every year from India. With rise in awareness of the benefits of organic products, the demands for such products has been increased in the national as well as international market. In order to meet the international standards India has switched to organic cultivation of basmati rice. Lack of knowledge, high input cost, low yield were the early challenges for the farmers adopting organic farming for the first time. Currently used organic techniques implies the use of organic manure, biofertilizers, crop rotation, mixed farming and integrated pest management. A combined effort is taken by farmers, the government and researchers has led to persistent growth in basmati rice trade in the international market. We begin this review by providing a brief introduction to the challenges faced by farmers and current status of Basmati rice trade. This is followed by an inclusive overview on the various techniques standardised for organic farming of basmati rice from cultivation to post harvest storage to export of the product.

Keywords: Basmati rice, Organic farming; Biofertilizer; Crop rotation, Green manure

Introduction

All through the green revolution, many countries adopted extensive use of chemical synthetic fertilizer, pesticides, weedicides and followed single crop cultivation to improve crop yield. In this period, increasing the yield was the only focus of researchers and agronomists (Evenson and Gollin, 2003). The unintentional cost of green revolution was loss of crop diversity, depletion of ground water level, ecological disturbance, deforestation, soil infertility, environmental pollution, pest build-up etc. (Pingali, 2012). Thus, the inorganic way of farming led to complete destruction of the ecosystem. Upon understanding the harmful effects, many countries decided to adopt organic

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way of farming. Organic farming involves restoring of the soil structure and its ecosystem to a healthy state by using eco-friendly methods and techniques.

Organic crop cultivation involves use of natural processes or substances for growing crop and pest management (Mahapatra *et al*., 2009). India initiated its first step towards organic farming in late 90s for the following benefits; conservation and restoration of natural resources, healthy food, low cost of cultivation, reuse of local organic waste and most important was the potential value of the product in global market (Surekha *et al*., 2010). Farmers practising chemical way of farming find it challenging to adopt organic way of farming. After following chemical way of farming for decades the first challenge was- How to do organic farming for a particular crop? Secondly, the widespread usage of synthetic fertilizers and pesticides ruined the soil structure to such a level that it can no longer support any plant growth without fertilizer (Shiva *et al*., 2004; Pingali, 2012). Hence the fields that has been used for inorganic way of farming for years when used for organic farming failed to give higher yields in the first few years till the fertile state of soil was restored. Moreover, basmati rice crop normally gives less yield as compared to non-aromatic rice varieties. Thus, the farmers had to face more loss in the earnings for first few years. Finally, organic farming needs higher initial investment than regular farming due to which poor farmers hesitate to adopt this technique. Developing countries like India cannot afford a complete adoption of organic farming as it has to feed a huge population. Initially, export crops like spices, fruits, vegetables, cocoa, basmati rice etc. which gave high returns were standardised for organic way of farming (Poyyamoli, 2017). Basmati rice received special attention as the Indian basmati rice has huge demand in the global market and it fetches highest income for the country upon export.

Basmati rice is the most popular aromatic rice variety known for its long, slender type of grain. An export quality of basmati rice concentrates on certain properties of the grain, namely length, aroma, taste, texture, shape and chemical composition (Siddiq *et al*., 1997). Basmati rice is the second most important agricultural products of India (44,14,605 metric tons) which upon export earned 4712 million US dollars in the year 2018-19 (Figure 1a). The United States of America (USA), Saudi Arabia, many other Gulf and European countries were the major importers of basmati rice from India in the year 2019-2020 (Figure 1a) (Data source: APEDA). There are twelve varieties notified as 'the true basmati rice' under the seed Act 1966. These varieties are Basmati 370, Basmati 386, Type 3 (Dehradun basmati), Karnal local/ Taraori Basmati (HBC-19), Basmati 217, Ranbir Basmati IET (11348), Basmati-1 (IET 10364), Pusa Basmati (PB)-1121, Punjab Basmati-1 (Bauni Basmati), Kasturi (IET-8580), Haryana Basmati-1 and Mahi Sugandha are the premium quality basmati

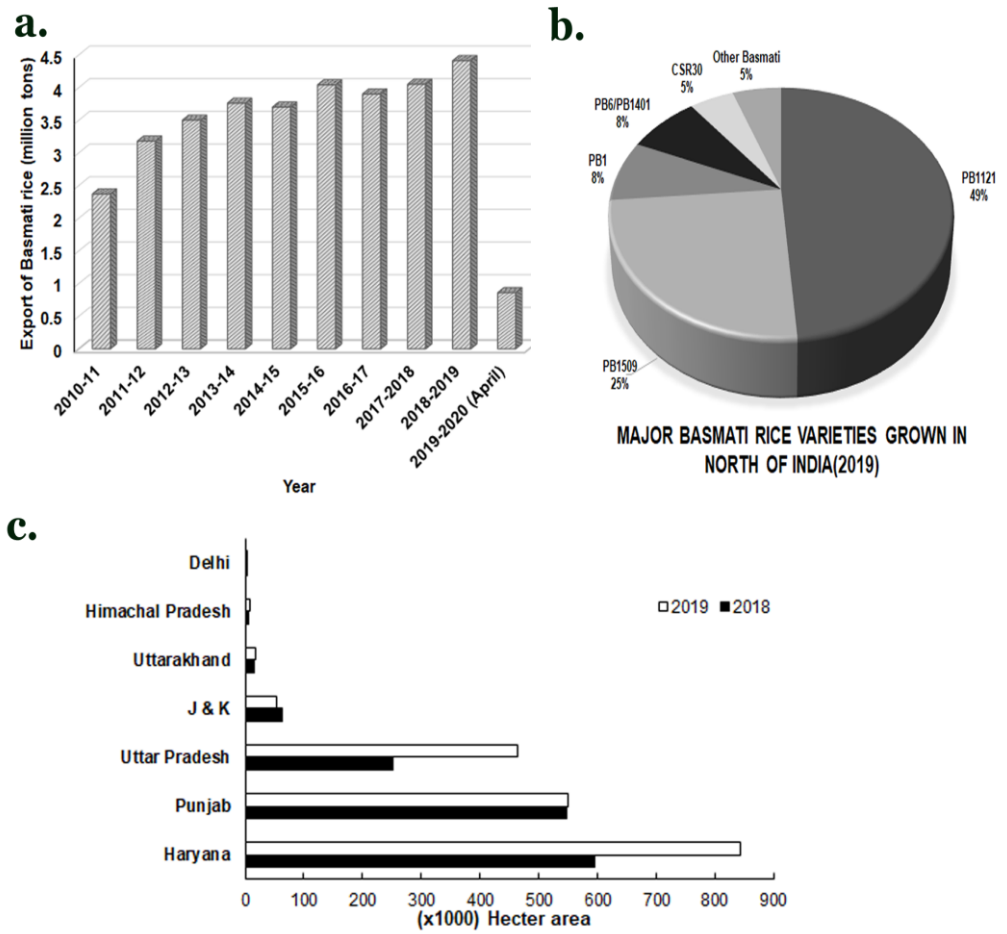

Figure 1. Basmati rice production and export from India: (a) the graph represents the year wise export of basmati rice from India; (b) the pie chart represents acreage covered under different varieties of basmati rice in the Northern states of India Pusa basmati (PB)1121 appears to be most popular among the farmers; (c) shows the state wise increase in area (hector) under basmati rice cultivation in Northern states of India from 2018 to 2018, it is found that a greater number of farmers are switching to basmati rice cultivation. (Data Source: APEDA, 2020)

rice varieties exported from India. Also, there are other varieties of basmati rice which are grown in India PB-1, PB-1401, CSR30 etc. which also have good value in Indian market. In the year 2019, PB 1121 and PB-1509 were the major variety grown in the northern states of India (Figure 1b). The climatic and geographical conditions of Himalayan slopes provide the suitable environment for basmati rice cultivation. North Indian states i.e. Haryana, Punjab, Uttar Pradesh, Uttarakhand, Himachal Pradesh, Delhi are the major producers of basmati rice and few regions of Jammu, Kashmir, Uttaranchal, Assam, West Bengal also cultivate this rice variety. Punjab and Haryana were the major producers of basmati rice in the year 2019 (APEDA). India and Pakistan have the geographical advantage to grow this crop. Countries like Pakistan, Kenya and Texas (United States of America) are competitors in the global market for basmati rice. The major challenge to Indian basmati rice market raised when the countries importing basmati rice started demanding organic basmati rice. Initially, it was difficult for Indian farmers to switch back to organic way of farming to cope up with the organic standards for export quality basmati rice. Since then many joint efforts were taken by the government, scientists and farmers to increase the total area under organic basmati rice cultivation.

Indian government initiatives towards organic cultivation of basmati rice

Organic crop cultivation involves use of organic fertilizer instead of synthetic chemicals, crop rotation or multiculture farming instead of monoculture and integrated pest management instead of chemical pesticides. For basmati rice cultivation, all above three steps were not well established in the beginning. Organic farming involves high initial investment which affects participation of poor farmers. In order to promote organic farming, the government of India launched various programmes (Table 1) which aided farmers at different stages of farming. Programmes like “National Programme for Organic Production” (NPOP) and the dedication of “National Institute of Organic Farming” (NIOF) were the important initial steps. The Indian government funded many research projects that directly or indirectly helped the improvement of organic farming techniques for various crops under Network project on organic farming (NPOF-ICAR). For basmati rice, application of organic manure, pest management, weed management etc. were standardised to give maximum yield for different varieties. Research on development of biofertilizer formulation and pest management techniques were promoted. The government also gave subsidy as an initial investment to farmers (Rs.5000/ hector) for promoting organic farming. All these efforts, eventually lead to an

increase in the area under organic cultivation from 42,000 hectares (2003-04) to 57,10,000 hectares in 2019 which is a proof of success of these programmes (Data source: Jaivik Bharat). Organic basmati rice was one of the major products which got special attention and its cultivation was boosted under the NPOP programme. Even today the Indian government organises events and training programmes to promoting organic farming. For basmati rice, the government established the Basmati Export Development Foundation (BEDF) which is dedicated in supporting basmati producers and traders. The department takes care of various aspects related to basmati rice viz., developing new varieties and techniques to improve yield and quality of basmati rice, promoting Indian basmati in global market, developing infrastructures required for Basmati rice promotion and research (APEDA).

Table 1. Various schemes and programmes promoting research and cultivation of organic crops

Programme or schemes released by the government of India*		Year
Aga Khan Rural Support Programme India	AKRSPI	1982
National Programme on Organic Production	NPOP	2001
Network Project on Organic Farming	NPOF	2004-05
Organic Basmati Production Program (Uttaranchal)	OBPP	2004
Rashtriya Krishi Viaks Yogana	RKVY	2007
National Mission for Sustainable Agriculture	NMSA	2014
Mission for Integrated Development of Horticulture	MIDH	2014
Paramparagat Krishi Vikas Yojana	PKVY	2015
Soil Health Management#	SHM	2015

*- organic basmati rice research and cultivation were boosted in during implementation of these programmes.

#- as soil health is restored by organic farming, this programme indirectly promoted organic farming of many crops including basmati rice (Poyyamoli, 2017).

Organic way of restoring the damaged soil for basmati rice cultivation

A fertile soil is characterized by its organic content, microorganism and other living forms like worms, ants, nematodes etc. Ideally, the organic content of a soil should be 0.8-1.5 %. (Shiva *et al*., 2004; NCOF). The soil ecosystem is restored by use of organic fertilizers and by avoiding of synthetic fertilizers. Basmati rice grows easily in any type of soil but for excellent growth heavy neutral soil like clay, loam clay with good water holding capacity is required.

After ploughing, combination of farm yard manure, vermicompost, compost (wet/dry), paddy straw, sunhemp, biogas slurry, poultry waste, oil cakes (neem/ castor) etc. are incorporated into the submerged water fields (Shiva *et al*., 2004). Blue green algae (BGA), *Azolla, Anabaena* sps, *Azotobacter, Azospirillum*, phosphate solubilising bacteria, mycorrhizal fungi and consortium of various plant growth promoting rhizobacteria (PGPR) are used as biofertilizers for basmati crop. Biofertilizers are microorganisms that enrich soil nutrient by their natural metabolic process. Biofertilizers are added just before or after plantation of rice seedling. Several studies are reported on combination of biofertilizer and organic manure different varieties of basmati rice (Table 2). Incorporation of blue-green algae (BGA), *Azolla*, vermicompost and farm yard manure to Pusa basmati-1, results in 114-116% increase in the yield of basmati rice (Singh *et al*., 2011). The combined use of PGPRs, namely, *Anabaena oscillarioides*, *Brevundimonas diminuta* and *Ochrobactrum anthropi* significantly increased the basmati rice yield of PB-2511 by 21.2%, as compared to the application of recommended dose of nitrogen-phosphorus-potassium (NPK) fertilizers (Rana *et al*., 2015). In Andhra Pradesh, for sandy-clay loam soil, application of farm yard manure, neem leaf manure, sheep manure and poultry manure significantly increased the yield of PB-1 and Tararoi basmati rice varieties (Rao *et al.,* 2013). Poultry manure is another easily available organic fertilizer which can alone replace the 50% of the recommended dose of NPK for basmati rice (Yadav and Yadav, 2015). The aroma of basmati rice is enhanced with application of farm yard manure, trailed by nitrogen fertilizer application. Zinc solubilizing PGPRs improved growth and yield of Pakistani basmati rice variety (Shakeel *et al*., 2015). Although organic farming avoids use of synthetic fertilizers, a fixed low amount of mineral nutrients like zinc sulphate $ZnSO_4$ (for zinc), potash K (for potassium), gypsum $CaSO_4$ (for sulphur) are allowed in organic farming depending upon the soil type (Srivastava *et al.*, 2014).

Even after use of organic manure and biofertilizers, the yield remains low for first few years as renovation of soil health is a time taking process. Nutrient mining remains as another major problem for small scale basmati rice farmers. The nutrient content from many organic manures is leached out while transportation of the manure from collection site to the field. If the loss of nutrient is controlled by well-planned interventions the yield can be further improved. For example, using straw bed for collecting livestock waste, covering compost or manure, purchasing farm yard manure, using biogas slurry etc. led to 40% increase in the yield of basmati rice (Ditzler *et al.*, 2018). Such trivial problems need to be identified at field level and this is possible when there is good communication between farmers and researchers.

Crop rotation and mixed farming

During green revolution, farmers grew only one type of crop throughout the year like wheat-paddy cropping system. This loop of monoculture farming lead to extensive use of same pesticides resulting in accumulation of pests. For example, brown hoppers, the pest found on paddy crops were accumulated during post green revolution in Punjab. The monoculture system also led to huge loss of soil biodiversity and depletion of soil nutrient (Shiva *et al*., 2004). Indian system of farming, prior to green revolution, followed crop rotation, mixed farming or multicultural system. In crop rotation, different crops are cultivated on the same land one after the other. As basmati rice is a Kharif crop (June-October; rainy season), the alternate crop should be a rabi crop (November-March). Wheat (*Triticum aestivum*) is the most popular rabi crop tested and is being used for crop rotation with basmati rice (Table 2). For this, farm yard manure and vermicompost are well standardised organic fertilizer (Table 2). Other than wheat, pulses are also grown in the rabi season. The leguminous plants form symbiotic association with nitrogen fixing bacteria and indirectly improve the soil quality. Growing legume crop to improve soil quality is known as green manuring. Prior to basmati rice framing, cultivation of *Sesbania aculeate*, cowpea, urad and mung bean improves the soil physio-chemical property (Nayyar and Chhibba, 2000). It has been studied that incorporation of *S. aculeate* increased basmati rice yield by 2.38%, 4.14%, and 10.82% in the first, second and third year of cultivation respectively than the cowpea and mung (Pooniya and Shivay, 2012). A field trail conducted by Indian agriculture research institute (IARI), showed that basmati rice-wheat-mung bean crop rotation system with organic manures increased basmati rice yield by 65% over the controls (Singh *et al.*, 2011). The combination of basmati rice- wheat-mung bean has found to have highest sustainability yield index when compared with rice, wheat, or mung bean alone with basmati rice (Singh *et al.*, 2011). For rice crop, increase in number of tillers directly improves the rice yield. Use of vermicompost and green manuring increases the development of effective tillers in Dehradhuni basmati rice variety (Singh *et al*., 2017). Another popular combination of cropping system followed is of basmati rice-wheat-local vegetables (Srivastava *et al.*, 2014). Local seasonal vegetables are grown when the field is free. Mixed cropping is another way of multicultural farming which includes growing different crops in the same field at the same time. As not all plants have same nutritive needs, the soil nutrient is not leached and pest build-up is also controlled. Organic cultivation of soybean along with basmati rice is the most followed mixed cropping system. The soybean plants are grown in intermittent rows alternate to every two rows of basmati rice;

hence this technique is also known as intercropping. Finger millet is another crop used in mixed farming with basmati rice. Both these crops yield good profit to the farmers in the organic food market (Srivastava *et al*., 2014).

Table 2. Different cropping system and fertilizers tested for growing organic basmati rice

Cropping System	Organic Fertilizer	Reference
Basmati rice-wheat	FYM	Kharub *et al.*, 2008
Basmati rice	FYM-Wheat residue	Davari *et al.*, 2012
Basmati rice	VC-Wheat residue-B	Davari *et al.*, 2012
Basmati rice-wheat	FYM-GM-B	Ram *et al.*, 2011
Basmati rice-wheat	GM-B	Ram *et al.*, 2011
Pusa Basmati 1- Wheat-Green gram	BGA-Azolla-VC-FYM	Singh *et al*., 2011
Basmati rice	GM-VC-neem cake	Mahajan *et al*., 2012
Basmati rice-wheat	FYM-VC-Karanj cake	Kumari *et al.*, 2013
Taraori Basmati	-	Sihi *et al.*, 2012
Pusa Basmati 1	-	Singh *et al*., 2012
Dehradum basmati	GM-VC-*Sesbania aculeata*	Singh *et al*., 2017

Key: Farm yard manure-FYM; Vermicompost-VC; Microbial Biofertilizer-B; Green Manure-GM

Eco-friendly way of controlling pest, disease and weeds

Pest and microbial diseases are major threat in the field which can cause enormous loss in the profit of basmati rice. Brown plant hopper, stem borer, rice leaf folder, rice gundhi bug, white backer plant hopper and rice hispa are the major pests of basmati rice (Table 3). Only 0.1% of the pesticide sprayed actually reaches the target pests while the rest reach the non-targeted beneficial insects or to the soil. Thus, extensive use of pesticide has indirectly led to an increase in the number of resistant pests in the field. National Centre for Integrated Pest Management (NCIPM) along with National Rice Research Institute (NRRI) released a basic IPM module which was tested in fields of northern India with basmati rice varieties PB 1, Taraori basmati, Dehraduni basmati, PB 1121 in the year 1998 to 2019 (Tanwar *et al.*, 2019). In this study, a higher basmati rice yield as well as a higher benefit to cost ratio was obtained in IPM as compared to regular farming practice. The best eco-friendly way of controlling pest involves use of systemic approach known as biointensive integrated pest management (BIPM) (Mohapatra, 2008, Reddy *et al*., 2012). BIPM considers both ecological and economic factors. First part in BIPM is to improve plants natural health and immunity. This involves proactive farming practices like crop rotation, mixed farming, growing resistant crop varieties,

using disease-free seeds, field sanitation, proper spacing of plants; alternate drying and wetting of land etc. also known as cultural control (Shiva *et al.,* 2004). The second part of BIPM is reactive practices which involves early detection of pest attack and taking immediate action to control spreading of the pest. This includes mechanical control, use of biocontrol agents, plant extracts (biopesticides) etc. to control growth of pest. In this section, we have reviewed the different methods that has been successfully used for IPM in basmati rice cultivation.

Table 3. List of pest, pathogens and weeds common to basmati rice crop in India

Pest	**Causative agent**
Brown plant hopper	*Nilaparvata lugens*
Rice hispa	*Dicladispa armigera*
Rice leaf folder	*Cnaphalocrocis medinalis*
Rice gundhi bug	*Leptocorisa oratoria*
Stem borer	*Scirpophaga incertulas*
Bacterial Disease	**Causative agent**
Bacterial leaf blight	*Xanthomonas oryzae pv. oryzae*
Fungal Disease	
Bakanae disease	*Gibberella fujikuroi,*
Brown spot	*Cercospora janseana, C. oryzae, Sphaerulina oryzina*
Neck blast	*Pyricularia grisea, P. oryzae*
Rice leaf blast	*Magnaporthe grisea*
Sheath blight	*Thanatephorus cucumeris, Rhizoctonia solani*
Viral	
Tungro	RTBV and RTSV
Weeds (Vernacular Name)	**Scientific name**
Banyard grass	*Echinochloa crusgalli*
Cattail millet	*Setaria glauca*
Club rushes	*Scripus* spp.
Cock's comb	*Celosia argentia*
Common sedge	*Cyperus difformis*
Crowfoot grass	*Dactylotenium aegypticum*
false daisy	*Eclipta alba*
Purple nut sedge	*Cyperus rotundus*
Wild rice	*Echinochloa colonum*
Yellow sedge	*Cyperus irri*

Key: RTBV- Rice tungro bacilliform virus; RTSV- Rice tungro spherical virus

Integrated pest management

For small fields, pest and its different stages can be physically removed from the plant. This method is also known as mechanical control and it is the best way of pest management. For large fields, installation of bird perches, light traps, sticky coloured plates, and pheromone traps are very effective methods (Shiva *et al.,* 2004). Few plant extracts are good source of biopesticides also known as biopreparations. Neem extract is found to be a good pest control agent, found effective against more than 200 species of insects. Extract *of Vitex negundo, Carica papaya, Aristolochia, Tinospora cordifolia, Annona squamosal, Ricinus communis, Nerium indicum, Calotropis procera,* chilli paste, garlic extract, tobacco leaf extract, and cow dung are used in different proportions to control different pests found on rice crop (Shiva *et al*., 2004). Another eco-friendly method includes use of various natural enemies of the pest (biocontrol agents) like pathogen, parasite or predators. This method is also known as biocontrol of pest. *Beauvaria bassiana, Metarizium anisopliae, Numeria rileyi, Verticillium* sps. are pest specific biocontrol agents (Shiva *et al.,* 2004). Bacterial biocontrol agents like *Bacillus thurengensis stenebrionis* and *B. thurengensis sandigo* are effective against insects belonging to class coleopteran (Shiva *et al*., 2004). Egg parasitoids like *Trichogramma* are minute insect wasps that are endoparasites found growing in insect eggs. *T. japonicum* and *T. chilonis* are used in fields against rice yellow stem borer and leaf folder for basmati crops (Tanwar *et al.,* 2019). Case study from Punjab state shows that following BIPM techniques increased the population of natural enemies of the pest in the fields (Sudhendu *et al.,* 2018). For successful application of IPM, immediate identification of the pest is very important. Many farmers fail to identify the pest attack or disease in the crop by observing the field or plant symptom. Hence, farmers should be educated about different pest and their life cycle so that they are alert and prepared prior to the pest attack. Also, farmers need an immediate helping hand to identify a microbial infection at an early stage. NRRI has developed and launched an app 'riceXpert' for farmers to identify pest and disease instantly. Using this app farmers will receive immediate suggestions for pest management (Tanwar *et al.,* 2019). Thus, communication between the farming community and the agriculture departments is very important for effective application of the BIPM knowledge.

The major microbial diseases that attack basmati rice crops are neck blast, bacterial blight, sheath blight, rice leaf blast and narrow brown spot (Table 3). These diseases can be controlled by following proper sanitization techniques and use of good quality of seeds. Fungal biocontrol agents like *Trichoderma harazianum, T. viride* are used to control soil borne fungal

diseases. Basmati rice seeds are pre-treated with Trichoderma prior to germination which allows the fungi to grow along with the plant in the soil and it prevents soils born fungal pathogen (Srivastava *et al.,* 2014). The incidence of Bakanae disease of rice caused by a fungi *Fusarium fujikuroi*, is controlled by application of endophytic bacterial strain of *B. oryzicola* YC7007 (Hossain *et al*., 2016). *Pseudomonas* (strain EA105), a rhizobacterium is been successfully used to control sheath blight caused by fungi *Magnaportha oryzae* (Spence *et al.,* 2014).

Resistant basmati rice varieties are promising

For certain rice diseases, like bacterial leaf blight, there are no specific chemicals to control the spread of the disease. The best solution for such case is to generate a disease resistant rice variety. Here extensive research by plant pathologist and rice crop breeders serves as boon for organic as well as regular synthetic farming. Institute for crop and agricultural research (ICAR) and rice research laboratories from India have developed many disease resistant basmati rice varieties. For example, leaf blight resistance rice genes *Xa21-xa5* and fungal blast resistance rice gene, Pi2-Pi54, which were identified in different rice varieties are now incorporated into Pusa basmati-1121 and Pusa basmati-6 rice background (Ellur *et al.,* 2016). Another basmati rice variety, Pusa-1718 developed by IARI which has its parentage from Pusa-1121 is gaining more popularity in Haryana due to its ability to fight against bacterial blight disease. Haryana Basmati-1 has resistance to blast disease and a pest, white backed plant hopper (APEDA). Pusa-1637 released recently is also resistant to fungal blast and bacterial blight diseases (APEDA). Thus, resistant varieties are more popular among the farmers as they have to invest less in IPM. However, pest and plant pathogens are constantly evolving so in near future they would be able to overgrow the resistant rice varieties. Hence, research in identifying new resistance genes against pest and diseases should move forward at a constant pace.

Hand on hand for weed control

Weeds are another menace to basmati rice cultivation. They scavenge the nutrients and sunlight from the actual crop. More than twelve different species of weeds are found in basmati rice fields (Table 3). These weeds scavenge the light and nutrients of the crop and thus affect the rice yield (Jaswal and Singh, 2019). The source of weeds are the seeds, soil, manure, vehicles, instruments, etc. used during the farming. Introduction of weeds can be minimized by taking

precautions at various stages of farming. Crop rotation helps to get rid of many weeds which are difficult to remove. Herbicides cannot be used in organic farming. Hand plucking (weeding) using labours is the only way of removing weeds. In order to reduce labour charges a rotar-hoe also known as con-weeder machine can be used in case of heavy weed (Srivastava *et al.,* 2014). Weeding for basmati rice is generally performed twice or thrice (in case of heavy weed) during the crop season. The first two round of weeding is done at 20-25 day and 40-45 days old rice crop. Interestingly, Jaswal and co-workers have shown that hand weeding improved overall yield of PB-1121 rice as compared to herbicide treated fields (Jaswal and Singh, 2019). Use of herbivorous fish like *Puniux gonianatus, Tilapia melanopleura, T. zilli* and *T. nilotica* also helps in getting rid of aquatic weeds of rice crop. Hand weeding is a money spending process for the farmers. However, the money is recovered later after selling the harvest. This step-in organic farming generates job opportunities for many unskilled local labourers.

Prevention of post-harvest pest attack

Basmati rice is harvested at the beginning of the winter season (October-November). The harvested crop is sun dried in the field for two-three days to reduce the moisture content. This is followed by threshing, winnowing, grading and followed by storing in gunny bags or plastic bags. In order to improve the cooking quality of the basmati rice, the rice is stored for longer time, this is also known as aging. Aging also increases the market value of the basmati rice. On contrary prolonged storage increases the risk of fungal, pest and rodent attacks. If basmati rice is not properly dried, it has high moisture content and it can promote fungal growth. The storage rooms must be kept clean, hygienic and must be free from rodents, ants and pests. Many mycotoxin producing fungi grows over stored rice (Table 4). This can be prevented by minimizing direct contact of rice bags with water. Proper Sun drying and exposure to activated charcoal significantly reduces the growth of aflatoxin producing *Aspergillus flavus* in stored basmati rice (Bedi and Agarwal, 2014). Another method to control fungal growth is to incorporate organic fungicides. When basmati rice was mixed with pomegranate and lemon peel powder, it completely inhibited growth of *A. flavus* (Naseer *et al.,* 2014). The stored rice is also attacked by insect pests that belong to coleoptera and lepidoptera order (Table 4) (Sinha *et al.,* 2010). Traditional methods can be used to prevent post-harvest pest attack which involves fire oil lamp trap to attract and kill insects. Smoking of the storage rooms with charcoal or neem leaves is recommended. Mechanical removal of damaged seeds before storage minimizes the risks of pest attack.

Another way of reducing the risk of pest attack is by accelerating the aging process. The optimum accelerated aging condition standardised for PB-1 is 43.4^{o}C temperature, 71% relative humidity for 11.4 days (Rayaguru *et al.*, 2011).

Table 4. List of pest and fungi infesting post-harvest stored rice

Pest (Vernacular name)	**Scientific name**
Rice weevil	*Sitophilus oryza*
Lesser grain borer	*Rhyzopertha dominica*
Khapra beetle	*Trogoderma granaria*
Red rust flour beetle	*Tribolium castaneum*
Saw-toothed grain beetle	*Oryzaephilus surinamensis*
Long headed flour beetle	*Latheticus oryzae*
Rice moth	*Corcyra cephalonica*
Almond moth	*Cadra cautella*
Indian meal moth	*Plodia interpunctella*
Mycotoxin producing fungi	**Mycotoxin**
***Aspergillus* spp.**	AflatoxinB1,-B2, ochratoxin A, sterigmatocystin
***Fusarium* spp.**	HT-2, T-2, fumonisin B1, gibberellic acid, moniliformin
***Penicillium* spp**	deoxinivaleno, fumonisin B1, beauvericin, fusaproliferin, penicillic acid, citreoviridin, citrinin, cyclopiazonic acid, cyclochlorotin, luteoskyrin, rugulosin, ochratoxin A
***Alternaria* spp**	Alternaria toxins
Ustilaginoidea virens	ustilaginoidins, ustiloxin

(Sinha *et al.*, 2010 and Gonçalves *et al.*, 2019)

Organic Basmati rice certification and export

Finding the right value for the product is the farmer's final struggle which depends on yield, quality, market value and the expenditure cost invested during the farming. Organic certification is the last payoff stage in organic basmati rice production. Many farmers cheat by using chemical fertiliser or pesticides to improve the yield and sell them as organic product. Thus, chemical testing of the harvest and getting the product certified is prerequisite for exporting organic basmati rice. Frequently basmati rice is also adulterated with non-basmati rice variety to earn more profit. For this, stringent techniques like DNA sequencing for the true basmati specific markers (short tandem repeats or microsatellite) are being used to identify fraud basmati (Fridez,

2016). In India, standards for organic certification for all agricultural products is given by National Program of Organic Production (Santacoloma, 2007). However, for export of basmati rice standards given by the importing country has to be followed. There is list of various testing laboratories approved by APEDA which perform tests required for organic certification of basmati rice for different countries. Farmers either directly get their harvest tested for chemical residues or they sell to private agents who look after the certification process. Usually, many private traders or companies adopt or sign contract with the entire village or farmers for organic basmati rice production. This system is also known as Internal control system (ICS) (Santacoloma, 2007). The ICS takes care of the supplies required for organic farming, initial investment, organic certification etc. These firms also perform regular inspection at different growth stages of basmati crop so that farmers don't lie or cheat the company. Thus, here the farmers just have to follow the instructions of the contractor. The government play very important role popularising basmati rise in the global market. For example, APEDA participates in international fair trade to promote Indian organic basmati rice in various international meets. The government also helps the farmers with subsidy during difficult times so that the trade flow is not affected. The government also plays role of key decision maker under situations of global threat like COVID19 pandemic, locust attack, economic recession etc. These are the situations where a common problem is faced by more than one country and the countries jointly work on finding solution. Thus, the government plays are very important role of mediator between the global market and the farming sector.

Residual effects of pesticides on basmati rice export

Presently, residual chemical pesticides or synthetic chemicals are major concern for Indian basmati rice exports. Many Indian agricultural exports are rejected due to higher chemical residues than the Maximum Residue Limit (MRL) criteria of the importing nations. In the year 2018, the export of basmati declined to many European countries like UK, Netherland, France, Italy, Germany, Sweden, Switzerland etc. (Figure 2). This decline in export occurred when the European Union (EU) government reduced the MRL of residual fungicide (Tricyclazole) from 1 part per million (ppm) to 0.01ppm (APEDA). Similarly, Saudi Arabia, the largest importer of basmati, decided to follow the EU import standards. As a result of this the basmati rice export reduced significantly in the year 2018-2019. Tricyclazole is a very cheap and easily available pesticide which is used by many farmers as an immediate solution for pest control. During organic farming of basmati rice, care has to be taken that

the crop is not exposed to synthetic chemicals, either from soil, neighbouring fields, rice mills, previous crop etc. The government and scientific bodies are working towards this problem. Punjab state of India is one of the major producers of organic basmati rice. In order to improve the export from the state, the state government has taken a severe action, based on which the state banned the use of carbendazim, thiamethoxam, triazofos, tricyclazole, buprofezin, carbofuran, propiconazole and thiophanate methyl for basmati rice as well as other crops grown in the state. Such strict action taken by the state government bodies will improve the quality of the crops at field level but at the same time will create an awareness on usage of such cheap pesticides on other crops as well.

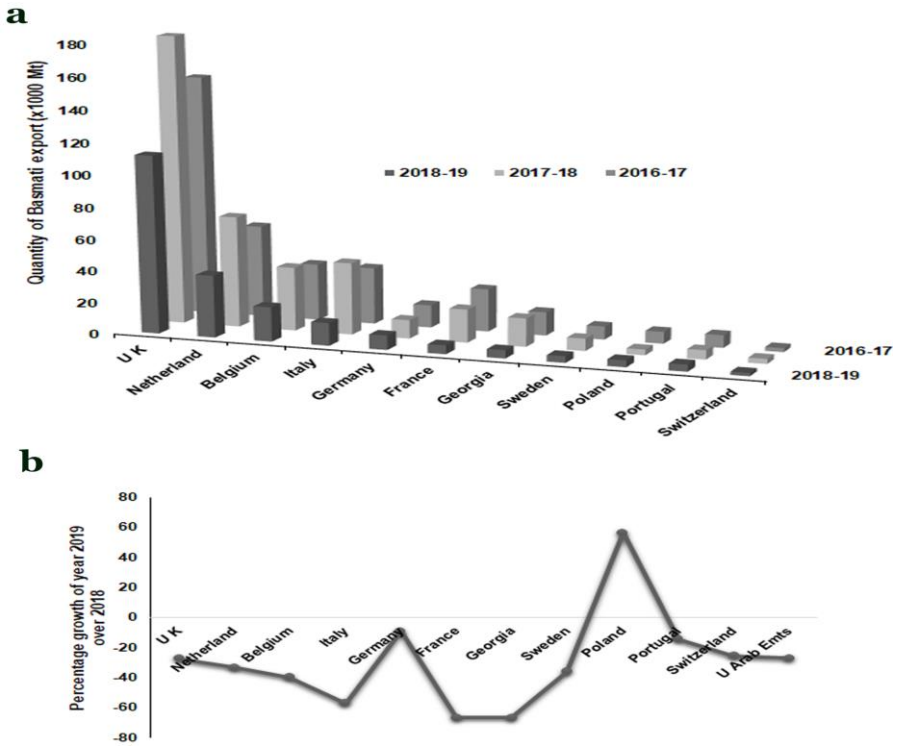

Figure 2. India's basmati rice export from 2016-2019 to different European countries. The graph (a) represents the export of basmati rice for few top importers from European countries from year 2016-19. The export increased for all the countries from the year 2016-17 to 2017-18 but the export declined in the year 2018-19 after European Union laid new guidelines for residual pesticides. The percentage growth in basmati rice export for 2019 over previous year has fallen for the given European countries except for Poland (Data Source: APEDA, 2020)

COVID19 Pandemic touched the basmati rice market

Currently, the entire world is facing corona virus disease 2019 (COVID19) pandemic attack. In the fear of spreading of infection, overall import and export of most of the commodities has been affected. As the global economy is affected, many countries are facing economic deficiencies leading to delay in payments to India for the imported basmati rice. In India, lock down of population migration in response to COVID19 pandemic has adversely affected the conditions of labour workers. Labour workers play crucial role in organic farming, loading and transportation of basmati rice from different places till the harvest reach the destination (consumer or other country). The agriculture sector was affected due to lack of manpower. Despite these drawbacks, the silver lining to the pandemic situation was seen the demand for aromatic and non-aromatic rice from India increased in the global market. Also, BEDF has disclosed that the price of the basmati rice has been increased by 10% (Rs 6300 to Rs7000 per quintal) in the global market in the pandemic year 2019-2020 (BEDF). Also, the export for basmati rice in 2019-20 has been increased by 0.9% from the previous year. In order to help the farmers in maintaining the trade flow and for promoting cultivation of aromatic and non-aromatic rice varieties, the Rice Export Promotion Forum (REPF) has released schemes which will help farmer to earn more income.

Conclusions and future aspects

In the world's eye India is hub of agricultural commodities. Over the years India has witnessed a steady increase in basmati rice export and the land coverage under organic basmati rice cultivation. The government, researchers and farmers have worked together for this growth in basmati rice. For constant growth of basmati rice market, each of the three group have to develop at their own level. Research has to be focused on developing new biotic and abiotic stress tolerant basmati rice varieties. Invention of new technologies for pest-weed control is also crucial. The government has to continue to work on popularising organic farming of basmati rice among farmers as well as in the global market. Organic certification is still an expensive and slow process in India. Many of the government policies still don't reach the remote farming community due to lack of communication. India is still facing the problem of having high level of residual pesticide in the export of basmati rice. For this, farmers should be educated about the pesticide usage. Many farmers are considering organic farming as an opportunity to earn more profits instead of

considering it as an eco-friendly method. Thus, farmers take organic farming casually and they use synthetic fertilizers and pesticides. Considering these issues, farmers should be educated about their environment and benefits of organic farming to their land. Farmers should form an organisation with help of government and researchers so that they are benefited with the policies released for them. In order to earn maximum profit, the farmer struggles to minimize the expenditure cost and this has to be achieved without affecting the yield and the quality of basmati rice. In order to accomplish this the research community along with the government must prioritize the well-being of the farming society for overall growth of Indian agriculture sector.

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