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किस्मों का प्रभाव आकलन

**Impact Assessment of Biofortified Varieties of
IARI**

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Impact Assessment of Biofortified varieties of IARI

By

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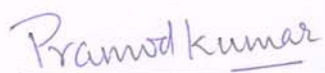
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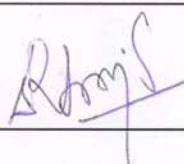
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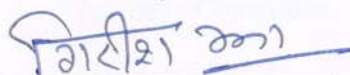
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CERTIFICATE

This is to certify that the thesis entitled “**Impact Assessment of Biofortified varieties of IARI**” submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science in Agricultural Economics**, to the faculty of the Post Graduate School, ICAR-Indian Agricultural Research Institute, New Delhi, embodies the results of a piece of bona fide research work carried out by **Ms. Geetha M. L, Roll No. 20918**, under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received during the course of investigation has been duly acknowledged by her.

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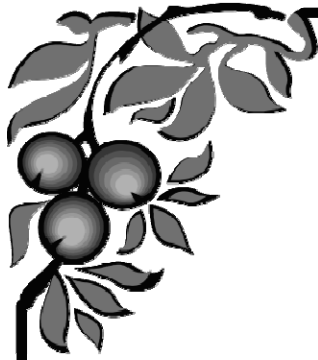
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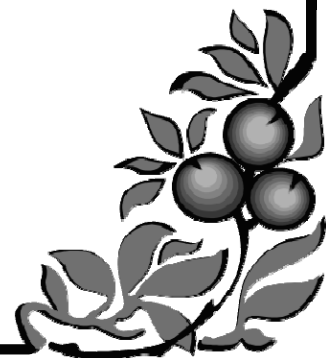
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(Geetha M. L)



*Dedicated to my
beloved parents*



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INTRODUCTION

1.1 Background

Since decades malnutrition has been the most serious challenge that the world is facing to achieve better health conditions and to make the globe a healthy hub. Malnutrition can take varied forms and it's affecting mainly the under developed and developing economies and affecting mostly the infants, children and the women including the adolescents as well. Malnutrition decreases the productivity of an average human being as it needs special care to tackle the problem and increases the cost of health care, and slows economic growth, which can sustain a cycle of poverty and ill health and more likely to affect people who are poor. An estimated 155 million children under the age of 5 suffered from stunting in 2016, while overweight or obese were 41 million and approximately 45 % of deaths among children under the age of 5 are associated with undernutrition (WHO).

1.1.1 Malnutrition

Malnutrition refers to deficiencies, excesses, or imbalances in a person's intake of energy or nutrients which hinders the social and economic prosperity. One of the various forms of malnutrition is micronutrient-related malnutrition, which includes deficiencies of vitamins and minerals in human diets. Further, The United Nations Children's Fund (UNICEF) defines malnutrition as a broad term commonly used as an alternative to undernutrition. People said to be malnourished if their diet does not provide adequate calories, protein, and micronutrients for growth and maintenance, or if unable to fully utilize the food they eat due to illness (under-nutrition) (UNICEF, 2006). According to Branca and Ferrari (2002), humans require at least 49 nutrients to meet their daily metabolic needs and inadequate consumption of any one of which results in adverse metabolic disturbances and turn in sickness, poor health, impaired development in children, and large economic costs to society.

Micronutrient deficiency is an all-pervasive nutritional problem in developing countries, resulting in impaired physical activities and cognitive under-development. In spite of the number of global and regional initiatives to control the main micronutrient deficiencies, such as vitamin A, zinc and iron, so-called hidden hunger remains a severe

health threat, particularly for pregnant women and children (Mason *et al.*, 2001). More than two billion people in the world suffer from micronutrient deficiencies caused by a dietary deficiency of vitamins and minerals (Allen *et al.*, 2006) and distribution of this global burden is highly skewed by age and region, the children below 5 years account for major shares in both the mortality and the morbidity burden. Out of total mortality burden, 93 % of the children in this age group account for vitamin A deficiency, 68 % to iron-deficiency anemia, and 100 % to zinc deficiency and for the total disease burden (mortality and morbidity), this age group accounts for 94, 57 and 100 %, respectively (Ezzati *et al.*, 2006). Although in many countries, the global burden of micronutrient deficiencies was reduced by more than half during 1990 to 2010, but it remains as the major public health problem and still ranks among the top causes of death and disability particularly in Africa south of the Sahara (Wong *et al.*, 2012). In India, 195 million people are undernourished (IFPRI, 2016). Asia and Africa bear the greatest share of all forms of malnutrition. In the year 2016, 56 % and 38 % of all stunted children below 5 years lived in Asia and Africa, respectively. Out of all overweight and wasted children, Asia and Africa account for 49 & 24 %, and 69 & 29 %, respectively (UNICEF, 2017).

1.1.2 Strategies to overcome malnutrition

To address micronutrient malnutrition, four strategies are commonly used, namely dietary diversification, fortification, supplementation, and biofortification.

1.1.2.1 Dietary diversification

It is the interventions that change food consumption at the household level in order to achieve a well-fed consumption and food security. It is vital to improve what people eat, in terms of variety, quality, and quantity (Food and Agricultural Organization, 1997). Under dietary diversification, consumers are encouraged to modify their eating behaviours, and by eating a wide variety of foods with different nutrients, they increase the levels of those that are necessary for the diet. Dietary diversification is undertaken mainly on types of food already available to the population, with modifications just to a consumer's choice of foods, i.e. by increasing the variety and quantity of micronutrient-rich foods, to decrease micronutrient deficiency, including animal-source foods (Gibson, 2014). Moreover, solutions to micronutrient malnutrition go hand-in-hand with ensuring food security, especially at the household level (Campos-Bowers and Wittenmyer, 2007). Most of the traditional

food cultures, such as the red palm oil, fish, meat and leafy green food complex of West Africa, are noted for delivering excellent nutritional quality (including vitamin A) at low cost and in a culturally acceptable way (Smith, 1998). In some places, dietary diversification has been successful in reducing malnutrition, for example in South Africa, increased consumption of foods rich in vitamin A, and awareness creation problematic areas have helped to reduce vitamin A deficiency among children (Faber *et al.*, 2002). For higher income class, developing the nutritional value of staple food crops has been of less concern since they have access to improved nutrition through dietary diversification (Morris and Sands, 2006), whereas it is not always an attainable one in developing countries since the poor people are deficient in purchasing power (Meenakshi *et al.*, 2010)

1.1.2.2 Fortification

It is the activity to intentionally increase the content of vital micronutrients in food to enhance the nutritional quality of the food supply and to provide a service to public health with minimal health risks (FAO, 2006). Since fortification of staple foods is socially acceptable, it can be used as a measure of addressing malnutrition and does not require the active participation of consumers or any change in buying, cooking or eating habits (Nestel, 1993). Food fortification has been used successfully to increase micronutrient levels in larger populations. In the year 1920, Iodine fortification of salt was introduced in the United States of America when it has been realized to prevent iodine deficiency in many developing and developed countries (Miller, 2004). Meanwhile it has challenges where, individuals who consume locally produced, unprocessed food are unlikely to benefit from fortification since it depends on centrally processed and marketed food vehicles (National Nutritional Council, 1994) and relies on broadly distributed, industrially processed food items, which are usually unaffordable to the poor consumers (Mayer, 2008). Fortified foods are expensive because of additional cost incurred while processing and must be consumed on a regular basis (FAO, 1996).

1.1.2.3 Supplementation

It is the term, which is used to describe the provision of relatively large doses of micronutrients, in the form of capsules, syrups or pills (Meenakshi *et al.*, 2009). These are administered periodically to people to reduce micronutrient deficiency like vitamin A capsules to pre-school children twice a year. It is the fastest way to control

micronutrient deficiency in individuals by attaining an optimal amount of a specific nutrient in a highly absorbable form (FAO, 2006). It is effective on a large scale, for instance, successful eradication of vitamin A deficiency in Vietnam and Indonesia and successes were due to regular and broad supplementation coverage. However, deficiencies may reoccur in times of economic or political crisis (Underwood, 1999). Vitamin A supplementation programmes which were carried out in 103 countries showed that coverage stagnated at 58 % (UNICEF, 2007). Nutritional Anaemia Control Programme in India, which has been in operation since 1970, showing little impact because of underfunding, logistical problems, mismanagement and poor compliance (Vijayaraghavan, 2002). Another disadvantage is that it is not cost-effective.

1.1.2.4 Biofortification

Biofortification is the method by which agronomic practices, conventional plant breeding, or modern biotechnology is applied to improve the dietary value of food crops. Biofortification differs from common fortification in that biofortification seeks to raise crop nutrient concentrations during plant growth rather than manually during crop processing. (WHO, 2018). It involves breeding staple food crops to be a rich source of many key micronutrients like iron, zinc, vitamin A, and iodine, so that by disseminating these crops in rural areas where deficiency is high and where households consume a sizable share of calories from staple foods (Bouis, 2002). Biofortification of staple food crops is one of the initiatives to achieve improved nutrition among the poor and is likely to be a cost-effective public health intervention, in comparison with commercial fortification and supplementation (Meenakshi *et al.*, 2010) and it is an important strategy to fight against micronutrient malnutrition through the introduction of locally adapted staple foods that are bred to be high in micronutrients (Bouis, 1999). It is also done by reducing levels of anti-nutrients in the staple foods that slow down the bio-availability and absorption of nutrients by increasing levels of substances that promote nutrient absorption and bioavailability and increasing nutrient content in the plants through selective plant breeding (Campos-Bowers & Wittenmyer, 2007).

A study reveals that the health status of deficient individuals will be improved by increased intake of micronutrients through biofortified crops (Haas *et al.*, 2005). An insufficient supply of vitamin A causes various problems, which includes visual difficulty in children, weak disease resistance in infants, problems in pregnant women, and sudden death of infants and these problems are common in developing nations.

A study found that pregnant women in developed nations are also suffering from vitamin A deficiency problem (Braunstein *et al.*, 2010). To overcome this problem, Genetic modification (GM) technology has provided a solution by developing rice with the help of GM technology at ETH Zurich (Swiss Federal Institute of Technology) and the University of Freiburg, which is known as golden rice and it is a source of Vitamin A (Ye *et al.*, 2000). Another study based on consumer acceptance behaviour regarding biofortified iron beans was conducted in Rural Rwanda, and the results showed that in the absence of information about the nutritional benefits, consumers were willing to pay higher premium rates on the red iron bean (RIB) variety than white iron bean variety (WIB). They observed that by providing nutrition information, the consumer demand for the WIB variety increased significantly (Oparinde *et al.*, 2015). In India also biofortification is emerging as one of the major initiatives in combating malnutrition. The biofortified varieties were developed in the crops like rice, maize, pearl millet, sorghum, cauliflower and cowpea with the focus of improving the content of zinc, iron and vitamin A and β - carotene. It was also estimated that in India, the annual burden of zinc deficiency in 2011 was 1.3 million disability-adjusted life years (DALY) lost and this burden could be lowered up to 35 % with the biofortified rice (Nirmala *et al.*, 2016). Banerji *et al.*, (2015) conducted an experiment on consumer acceptance towards biofortified high-iron pearl millet (HIPM) in Maharashtra, India. As biofortification with minerals does not change the color or the appearance even in the absence of nutrition information, consumers allocate a significant premium to the HIPM variety compared to the local variety and they also observed that, with the nutrition information, an international branding and other sensory characteristics resulted in increased premium for HIPM. The success of biofortification depends on various factors, including the degree to which biofortified staples which are adopted by farmers and accepted by the consumers, and its cost-effectiveness (Unnevehr *et al.*, 2007). A number of studies have documented the relative cost-effectiveness of biofortification and it helps to fight nutrient deficiency especially in low-income population and rural areas.

1.2 The need for the study

India is ranked as one of the world's highest rates of malnutrition (WHO, 2018), biofortification could prove to be an essential strategy for fighting against micronutrient deficiency. Thus, there is a need for an in-depth study regarding the availability,

benefits, and costs of introducing biofortified varieties. Dietary behavior and choices are generally directed towards foods and not on the nutrients, nutrient content alone is unlikely to be sufficient reason for acceptance. In some cases, it may alter cooking, storage or sensory qualities, all of which affect its acceptance (Johns and Eyzaguirre, 2007). Therefore, there arose a need for a study that would produce the information on the level of acceptance, perceptions and willingness to pay (WTP) for the biofortified products.

1.3 Objectives of the study

This study attempted to analyse the cost involved in developing biofortified varieties and its returns in terms of health benefits. The study also helped us to measure the level of acceptance, perceptions, and magnitude of WTP for biofortified varieties among stakeholders (producers, consumers, processors and commission agents). With this backdrop, the present study “Impact Assessment of Biofortified varieties of IARI” was proposed with the following objectives.

1. To study the status of biofortified varieties in India
2. To analyze the cost of development of selected IARI biofortified varieties and quantification of ex-ante health benefits
3. To examine the perception of stakeholders about the biofortified varieties and willingness to pay by consumers

1.4 Organization of the thesis

This thesis comprises of six chapters. The first chapter consists of an introductory part, the second chapter discusses the literature review pertinent to the study. Chapter three discusses the research design and methodology. This comprises the data, methods and analytical tools and the detailed description of the entire research process, the area of study, the sampling framework as well as the models used in the analysis of the different data sets. Chapter four presents comprehensively the results of the study. Chapter five deals with the detailed discussion on results. The sixth and the final chapter presents the summary of the study and conclusions, and policy implications emanating from the study.

REVIEW OF LITERATURE

In this chapter, the review of the literature on several aspects pertaining to impact assessment of biofortified varieties has been presented. An attempt has been made to review the work done in India as well as in abroad on biofortification for better understanding of the topic and to identify potential areas for research, knowledge gaps, analytical techniques used and to interpret the results. The previous work done has been presented under the following heads:

2.1 Status of the biofortified varieties

Qaim *et al.* (2007) reported that micronutrient malnutrition was a serious public health problem in many developing countries and in spite of the number of interventions taken with the objective to build micronutrient densities in staple crops, yet their overall coverage was moderately limited. The study revealed that biofortification was a self-targeting approach and more sustainable than alternative micronutrient interventions and the factors which influence future impacts were micronutrient content, micronutrient retention, bioavailability, farmer adoption, and consumer acceptance. Ex-ante studies from India and other nations have suggested that biofortified crops can cost-effectively reduce the risk of micronutrient malnutrition when aimed at particular circumstances.

Saltzman *et al.* (2013) in their study found out that there existed a major gap in knowledge with respect to biofortified crops and in order to ensure greater adoption and consumption of biofortified crops requires additional delivery and marketing research activities. They also told that agricultural research centers need to adopt breeding for nutrient density crops. The results of efficacy and effectiveness studies, along with recent successes in delivery, provided evidence that for combating hidden hunger, biofortification was a cost-effective approach and a promising strategy.

Bouis and Saltzman (2017) made a review of evidence from Harvest Plus. They assessed that there were some main difficulties to reach one billion individuals by 2030, such as incorporating biofortified features into public plant breeding programmes, building consumer demand, and incorporating biofortification into public and private policies, programs, and investments. To achieve its maximum

capacity, biofortification must be integrated as a core activity within the range of global institutions which requires critical elements like supply, policy and demand. While they recommended that efforts must keep on in integrating biofortification in the policies at all scales.

Okello *et al.* (2018) studied the effect of agriculture-nutrition education and extension services on the adoption and diffusion of biofortified crops in Kenya. The study revealed that biofortification of staple crops is attaining global recognition and showed that intensive agriculture-nutrition education and extension programs help in increasing the likelihood of adoption and diffusion of biofortified crops.

2.2 Cost of development of biofortified varieties and their health benefits

Dreher *et al.* (2003) carried out a study to compare the cost-effectiveness of conventional and marker-assisted maize breeding in Mexico at the International Maize and Wheat Improvement Centre (CIMMYT) by using a spreadsheet-based budgeting approach. The cost function of the breeding program was estimated by examining each operation within the programme and estimating the fixed and variable costs of that operation. Costs were calculated for both field operations and laboratory procedures. For field operations costs were estimated on per hectare basis and for laboratory procedures costs were estimated at a scale reflecting actual practice at CIMMYT. The study identified the importance of spreadsheet-based budgeting tools which can be used in applied breeding programs in order to improve the efficiency of current protocols and to inform decisions regarding upcoming technology choices.

In 192 religious sisters living in 10 convents around Metro Manila, Philippines, the effectiveness of consuming high-iron rice during a 9-month feeding trial was evaluated by Haas *et al.* (2005). Daily food consumption was monitored by randomly assigning to devour either high-iron rice or a local variety of control rice. They found that the high-iron rice contributed 1.79 mg Fe/day to the diet rather than 0.37 mg Fe/day from the control rice. At the point when compared with controls, the 17 % difference in total dietary iron consumption was noticed and resulted in a modest increase in serum ferritin and total body iron and no increase in haemoglobin. Non-anaemic subjects' response was greater for ferritin and body iron resulting in a 20 % increase after control for baseline values and daily rice consumption. Improvements in iron status were found in those non-anaemic women who had the lowest baseline iron status. Without any changes in diet, it was efficacious in

enhancing iron stores of women with iron-poor diets in the developing world by the Consumption of biofortified rice.

Brennan and Martin (2006) studied the detailed cost structure and the nature of the cost function faced by the plant breeders for a Wheat Breeding Program in Australia. The data used in this paper was based on a hypothetical breeding program in which they used a modified pedigree selection method and for different stages of breeding operations, separate costs were estimated. The total costs were estimated for each operation, and then for each stage of the program which includes trial specifications (sites, replications, checks), site and data management, labor inputs, operating inputs, travel, and capital equipment. The study indicated that better understanding of the cost function allowed the implications for the potential usages of latest breeding technologies which help to increase the efficiency of breeding programs and acted as a basis for measuring the costs of different breeding programs which vary with the size.

Stein *et al.* (2007) estimated the effects of zinc biofortification of rice and wheat on public health in India and also estimated the cost-effectiveness using disability-adjusted life years (DALYs). They expressed the burden of zinc deficiency (ZnD) in terms of DALYs lost and the data of zinc intakes were taken from 55th household food consumption expenditure survey of the National Sample Survey Office (NSSO) which consists of data from 1,20,000 households in India and attributed to household members based on the equivalent weights of the adults. Remarkable effects were noted on increased intakes of zinc from biofortified rice and wheat which were interpreted concerning improvement in health under pessimistic and optimistic scenarios in comparison to alternative micronutrient interventions and international standards. They reported that biofortification of rice and wheat reduces the burden of zinc deficiency by 20 to 51 % and which helps to save 0.6 to 1.4 million DALYs each year and the children account for 18,350 or even 48,100. The cost for saving one DALY totals to \$US 0.73 to 7.31 under optimistic and pessimistic scenarios respectively and the results revealed that the cost of saving 1 DALY using biofortification was lower than that of the other interventions and hence it is a cost-effective way to decrease the health burden.

Stein *et al.* (2008) proposed a methodology for ex-ante impact assessment of iron biofortification in India, where they used a large and representative data set of

household food consumption expenditure of with 1,20,000 households and consumption details for 140 food items from NSSO for different target groups and regions and the effects of iron-rich rice and wheat varieties were simulated at the household level. The study indicated that iron biofortification of rice and wheat have considerable potential health benefits and the disease burden associated with iron deficiency under pessimistic scenario could be reduced by 19 %, and the cost per DALY saved is US\$5.39 and in an optimistic scenario, the burden could be reduced by 58 %, and DALY saved declined to 46 %.

Meenakshi *et al.* (2010) analyzed the cost-effectiveness of biofortified crops by using the modified DALY Approach and estimated the costs and benefits of biofortification of globally important staple food crops with provitamin A, zinc, and iron for twelve countries in Africa, Asia, and Latin America (Bangladesh, Brazil, Democratic Republic of Congo, Ethiopia, Honduras, India, Kenya, Nicaragua, Nigeria, Pakistan, Philippines and Uganda). In their study, they found that the intervention can make a substantial impact in a highly cost-effective way on the burden of micronutrient deficiencies in the developing world and the results of the study differed by crop, micronutrient and country.

De Steur *et al.* (2012) estimated the potential health benefits and cost-effectiveness of multi-biofortification which was directed in China. Using the DALY framework, the annual health burden of the four micronutrient deficiencies in China was estimated as 10.6 million DALYs. The results revealed that by introducing multi-biofortified rice could lower the burden by up to 46 %. Under optimistic assumptions, the cost per DALY saved would be around US\$ 2 and it would remain below US\$ 10 even under pessimistic assumptions. This study concluded that given the huge positive health impact and low recurrent costs of multi-biofortification, this intervention could be a cost-effective intervention.

Hotz *et al.* (2012) performed a randomized, controlled efficacy survey of a large-scale intervention to promote the development and consumption of household Orange Sweet Potato (OSP) using integrated agricultural, behavioral change and marketing elements in rural Mozambique. In their study, a low-intensity (1 year) and high intensity (nearly 3 years) training models were compared. The intervention resulted in substantial net increase in intakes of OSP (Model 1: 46, 48 and 97 g / day)

and intakes of vitamin A (Model 1: 263, 254 and 492 mg equivalents of retinol activity / day) among younger kids, elderly children and women, respectively. OSP accounted for 47 % to 60 % of all sweet potato consumed and among reference children, provided with 80 % of total vitamin A intakes.

Nirmala *et al.* (2016) measured the possible impact of zinc-biofortified rice using DALYs saved. They estimated the effect of the difference in the number of DALYs attributable to zinc deficiency before and after the introduction of the zinc-biofortified rice variety, 'DRR Dhan 45'. The study noticed that current zinc-content of the popular varieties was about 13 ppm and in the biofortified rice was 23 to 24 ppm with a potential increase of 80 %. It was observed in India that the calculated annual burden of zinc deficiency in 2011 was 1.3 million DALYs lost and with biofortified rice, the burden could be lowered up to 35 %. The analysis revealed that under the pessimistic scenario and optimistic scenario the cost of saving one healthy life year through zinc biofortification were US\$ 2 and US\$ 3, respectively.

2.3 Perception of the biofortified variety and willingness to pay

Luchini *et al.* (2003) studied the factors that affect farmer's willingness to pay for quality sweet potato planting materials in Tanzania by using seeming unrelated regression (SUR) model. The study elicited several willingness to pay for three health programmes which include heart disease, breast cancer and service of helicopter ambulance by using single contingent valuation survey in health care. In their study, they compared the application of independent Ordinary Least Square Regressions (OLS) for each programme with simultaneous estimations using SUR. The results indicated that separate estimations could lead to model misspecification because they did not taken into account the fact that joint evaluation exogenously provides a reference structure to the respondent, in which it affects the estimates of willingness to pay for each of the programmes. They found out that the use of SUR model improved efficiency of the willingness to pay estimates and willingness to pay equations for all the programmes were significantly correlated through their error terms, which gave further evidence that some common factors which were not explicitly observed in the survey, were jointly influencing the respondent's willingness to pay for the programmes.

Combris *et al.* (2007) conducted an investigation to know how the information on quality attributes affects the consumers' willingness to pay for pearl, a study

conducted in Portugal. The objective of the study was to compare the relative influences of attributes which are directly observable, like the appearance of pears, experience attributes like taste and credence attributes like food safety, which cannot be evaluated directly by the consumers. The study revealed that consumers were willing to pay significantly more for fully ripened pears and for better quality assurances such as the absence of pesticides in the pears. It also revealed that the sensory intrinsic attributes related to taste outperformed the assurance of food safety in driving the buying behavior and even when the consumers were informed about safer products, they still chose the tasty alternative. The study also compared willingness to pay for quality planting materials of both biofortified and non-biofortified crops which were similar in all aspect except that one was high in vitamin A (orange-fleshed) while the other was not rich in vitamin A (white-fleshed).

Tomlins *et al.* (2007) conducted sensory testing to evaluate the flavour profile and consumer acceptability of four sweet potato cultivars that differed in β - carotene content in Tanzania. Sensory testing was undertaken with 94 school children and 59 mothers with preschool children with two cultivars of orange-fleshed sweet potatoes (OFSPs), and the other two of pale-fleshed sweet potatoes (PFSPs). Consumer acceptability was calculated based on the sensory evaluation of cooked sweet potatoes by scoring their acceptability using a category scale. The results showed that OFSPs and PFSPs have distinct differences in sensory profile and the former were more acceptable than the traditional cultivars.

Groote and Kimenju (2008) studied consumers' preferences for white maize in East and Southern Africa. In their study, urban consumers' willingness to pay (WTP) for yellow maize was estimated, using a semi-double-bounded logistic model based on the assumption that individuals know their preferences with certainty. The survey comprised 600 maize consumers in Nairobi, Kenya, which was held in 2003, and consumers chose by using a stratified two-stage approach. Results revealed that Consumers showed a solid preference for white maize and minority would purchase yellow maize at the same price as white maize, and fewer consumers in the posho mills (24 %) and kiosks (19 %) than in the supermarkets (34 %) would do as such. On average, consumers require a price discount of 37 % to accept yellow maize. This discount was less at the posho mills (35 %) and kiosks (37 %) than in the supermarkets (48 %). The average premium for fortified maize was significantly less

than the discount for yellow i.e. 5.9 % for those aware and 7.4 % for those unaware. 76 % of the respondents knew about the presence of fortified meal and they generally showed an interest. Furthermore, Consumer preferences were impacted by socioeconomic factors and showed that women have a more grounded preference for both white maize and fortified maize than men, and consumers with more education and income have a more grounded preference for white maize. Overall, Consumers from Western Kenya had a lower preference for white, while those from Central Kenya had a more grounded preference for fortified maize.

Stevens and Winter-Nelson (2008) examined the acceptance of provitamin-A biofortified maize through taste tests and a trading experiment which was a framed field experiment conducted in Maputo, Mozambique. All in all, respondents rated the taste, texture and appearance of their local white maize over an orange, biofortified range and a white variety with a texture and flavor comparable to that of biofortified maize. Results showed that a large share of participants in a framed experiment accepted offers to trade local white maize meal for a meal from the biofortified maize and household size, the presence of small children, dietary diversity, and perceived taste were statistically significant determinants of acceptance. At the mean values, a 10 % decrease in the price of orange maize relative to white resulted in an increase in the probability of acceptance of about 1.5 % points. The predicted probability of acceptance drops from 48 % to 37 % when there was a 50 % price premium on the biofortified product. They found that current white maize preferences do not block the acceptance of orange biofortified varieties and that provitamin-A biofortified maize could be a self-targeting dietary intervention.

De Groote *et al.* (2010) estimated WTP for food quality, considering yellow versus fortified maize meal by using Becker-DeGroot-Marschak (BDM) individual auction mechanism. The rural consumers were presented with three types of maize meal i.e. plain white, plain yellow and fortified white, then requested them to bid for the different one. The study showed that consumers were greatly interested in nutritionally enhanced maize and were willing to pay a premium of 24 % for maize fortified with minerals and vitamins. In one study zone, where yellow maize was most commonly preferred showed a higher preference for the yellow plain maize meal than the white plain maize meal and willing to pay a premium of 4.9 % for the yellow plain maize meal.

Hugo *et al.* (2010) assessed WTP for orange, biofortified maize in Ghana using three elicitation methods. Rural consumers' WTP was assessed mainly by using Becker-DeGroot-Marschak (BDM), choice experiments and group auctions of rural consumers. The survey was conducted on a sample of 696 respondents. The results found out that colour preferences were principally affected by regional factors and the information that the consumer has about the biofortified maize. They recommended that proper informational messages should differ by regions, and based on the context and argued that the colour of biofortified maize should therefore not be seen as a major impediment.

A study on the acceptability of pro-vitamin A orange maize by using both home use sensory evaluation and central location sensory evaluation methods was conducted by Meenakshi *et al.* (2010). The objective was to determine the consumer acceptance of biofortified maize in rural Zambia. For home use sensory evaluation, 279 households were given two kilograms of biofortified maize flour and two kilograms of conventional maize flour to prepare stiff porridge and asked them to evaluate based on the sensory characteristics and for central location testing, 208 rural consumers participated in the sensory evaluation of stiff porridge. The study found out that orange maize was liked by the rural consumers in Zambia and the negative perception of yellow maize did not affect the acceptability of orange maize and the study showed similar findings from home use testing and central location testing.

Chowdhury *et al.* (2011) by using choice experiment with the real product in Uganda, quantified the magnitude of the discount in consumers' WTP which was associated with biofortified staple crops that were high in pro-vitamin A. The study revealed that with nutrition information, consumers were willing to pay a premium of nearly 25 % for the deep-orange variety relative to the white variety which was significant at the 10 % level and with no nutrition information, there was no premium for orange variety relative to the white variety. In general, the taste plays a vital role in consumers' acceptance, and the nutrition information translated into substantial premiums for the biofortified variety. They also found that there was substantial hypothetical bias in the WTP for the new varieties.

Pillay *et al.* (2011) assessed the acceptance of popular maize food products which was prepared with yellow provitamin A biofortified maize varieties. Statistical Package for Social Sciences (SPSS) was used to analyse the data of 212 subjects

between the ages of three and 55 years from rural KwaZulu-Natal. Results showed that preschool children preferred yellow maize to white maize food products and in primary school children, no statistically significant difference in preference was seen. Secondary school and adult subjects preferred white maize to yellow maize and in focus group discussions, it was confirmed the preference for white maize by the adults. The results of the research indicated that yellow provitamin A biofortified maize may be successful as a unique approach to address the major vitamin A deficiency issue. However, this approach is unlikely to succeed in elderly communities unless other approaches, including extensive nutrition education programs on the dietary advantages of maize, targeting the market price at which yellow maize was sold, improving its accessibility in local grocery stores, and improving its sensory characteristics through breeding, have been enacted.

Steur (2011) made an ex-ante analysis for the market potential of foliate biofortified rice (FBR) in China. The data was collected from 14 auction sessions which consist of 252 women of childbearing age in Taigu, a rural county of Shanxi Province in 2011. The results found out that relatively high acceptance for FBR i.e., 62.2 % and the consumers were willing to pay 33.7 % higher price than for regular rice.

Birol *et al.* (2015) studied the consumer acceptance of food products of biofortified crops on 5 crops across 7 countries in Africa, Asia, and Latin America by using interdisciplinary research methods and also studied the factors which were responsible for affecting the acceptance of food products. Using sensory evaluation studies with trained expert panels, they found out that for all the products i.e. for Orange Sweet Potato in Uganda, maize in Zambia and Ghana, and iron bean varieties in Rwanda, they were able to differentiate among biofortified and non-biofortified samples with respect to taste, odor, appearance, and texture. In hedonic testing, the results revealed that for biofortified crops with visible nutrition traits requires no information regarding the nutritional benefits. In the same manner, the results of willingness to pay revealed that in the absence of information, consumers were willing to pay for food products made with biofortified varieties when their traits are visible and in the presence of nutrition information, consumers willing to pay a significant price premium which ranged from 8 % to 50 % for biofortified food

products when compared to conventional food products. They highlighted that the breeders should develop those biofortified crops that were liked by consumers and also one should focus on the development of appropriate marketing and awareness among consumers by information campaigns which would aid in switching consumption of food products from traditional to biofortified crops.

Kajale and Becker (2015) estimated students' WTP for golden rice (GR) by using the double-bounded contingent valuation method. They utilized a data set which was gathered in early 2009 at two locations, Delhi University and Bangalore University in India by face-to-face interviews. The consumer risk-benefit perceptions, knowledge about genetically modified factors (GMF), sociodemographic variables and GR were recorded. They found that nearly 55 % of the students were willing to buy GR at the same price as that of conventional rice, and around 85 % at a certain discount. The estimated mean willingness to pay was a 4 % price premium and likewise discovered that global and personal benefit perceptions had a positive significant influence, and risk perceptions and sociodemographic variables had an insignificant influence on willingness to pay for golden rice. In general, the findings indicated that India has a potential market for golden rice.

Mwiti *et al.* (2015) examined the WTP for quality sweet potato planting materials which include planting material of biofortified crops such as the orange-fleshed sweet potato (OFSP), where most of the studies focused on the willingness to pay by consumers for the final product and shows there was, indeed, demand for biofortified food. The data was collected from 732 farm households stratified by participation in a sweet potato project implemented in Tanzania between 2009 and 2013. In this study, the willingness to pay for both the biofortified and non-biofortified varieties of sweet potato were jointly assessed by using seemingly unrelated regression which controls for the correlations in willingness to pay bids for the quality planting materials of biofortified as well as non-biofortified sweet potato varieties. The result revealed that the demand by the farmers for quality planting materials of non OFSP varieties was more than the OFSP varieties and the distance to the source of quality planting materials reduced demand for such materials. Therefore, there was a need to decentralize multiplication and make it available locally and also the need to focus breeding on varietal attributes in addition to the agronomic attributes.

Oparinde *et al.* (2015) studied consumers' behaviour on acceptance of biofortified iron beans in Rural Rwanda. They investigated the effect of nutrition information, information frame and the frequency of providing the information on consumer WTP for iron bean varieties using the BDM mechanism. To select households randomly within the districts, multi-stage cluster sampling procedure was employed. The results showed that in the absence of information about the nutritional benefits, consumers were willing to pay higher premium rates on the red iron bean (RIB) variety than white iron bean variety (WIB). While comparing with the local variety, participants with no information were willing to pay a premium of about 7 % for the RIB variety and a discount of about 11 % for the WIB variety and the participants with information were willing to pay a premium ranging from 13 % to 17 % for the RIB variety and a discount ranging from 6 % to 14 % for the WIB variety. They also observed that by providing nutrition information, the consumer demand for the WIB variety increased significantly.

Banerji *et al.* (2016) conducted an experiment on consumer acceptance towards biofortified high-iron pearl millet (HIPM) in Maharashtra, India. They employed BDM mechanism and used sensory evaluation methods to estimate consumers demand and the study was conducted in 12 central locations which include wedding halls, government buildings, or schools, depending on the town. As biofortification with minerals does not change the colour or the appearance even in the absence of nutrition information, consumers allocate a significant premium to the HIPM variety compared to the local variety and they also observed that, with the nutrition information, an international branding and other sensory characteristics resulted in increased premium for HIPM. The mean WTP for HIPM increased by 12 % and for the state brand and certification treatment, the mean WTP increased by 7 %.

MATERIALS AND METHOD

The present study on “Impact Assessment of Biofortified varieties of IARI” was carried out using both primary and secondary data. This chapter gives the details of various data sources and the methodology used to accomplish the stated objectives of the study. This chapter contains sections, the first section discusses various data sources used for the study and the second section discusses the various analytical tools used in the study.

3.1 Data sources

Both primary and secondary data were used. To study the status of the biofortified varieties in India, the following data on bio-fortified crops such as varieties released and its characteristics, the origin of development, its area of adoption, total area, production and productivity as well as in major producing states along with their micronutrient contents were obtained from various government and authenticated sources like ICAR-IARI, ICRISAT, Seed net portal, AICRP reports, Harvest Plus, ICAR-Directorate of Rice Research, and from other related sources.

To calculate the cost of development of selected IARI biofortified varieties, primary data on cost structure was collected, which includes the cost of germplasm, cost of selection of parents, costs incurred for each operation and inputs used while developing a variety. The number of years a variety took for development and each year various costs involved are compiled such as material inputs, manpower such as scientific, technical, administrative, labour, etc. was collected and then fixed costs such as land rent, depreciation, some fixed costs associated crop group for research and development were apportioned based on the number of varieties developed during that period. Apart from this, the standard cost of cultivation techniques was employed for working the on-farm trials conducted in each year. The study also focused on any extra efforts involved in introducing any particular biofortified traits into a variety in comparison to non-biofortified variety. In order to work out the ex-ante health benefits of biofortified varieties, secondary data from National Sample Survey Office (NSSO), Ministry of Home Affairs, the Agriculture Census, 2010-11,

Directorate of Economics and Statistics (DES), Ministry of Agriculture, Govt. of India, The World Health Organization (WHO) and the Ministry of Statistics and Programme Implementation (MOSPI) were utilized. In the third objective, primary data was used to study the awareness, perception, and willingness to pay for the biofortified product. The sampling plan discussed in details in the next section.

3.2 Sampling Framework

Primary data were collected from both urban and rural areas to have a better understanding of both the classes. Urban consumers were selected from NCT (National Capital Territory) region. For the selection of the study areas in NCT, the areas which were having the biggest shopping complexes were listed out and four regions has been selected and in each region one shopping mall has been chosen. Face to face interviews was conducted by using a pre-tested schedule for those who are visiting shopping malls. Therefore, it is to be noted that the survey conducted only among the consumers those who have visited the mall and cannot be generalized. The survey has been continued in such a way that in each region, at least 15 respondents those who were aware about biofortified varieties and in total minimum 60 respondents those who are aware reached from the four regions. The schedule consists of two parts. In the first part, questions regarding perception, knowledge and other sociodemographic variables and in the second part, consists of questions regarding the biofortified product.

The rural consumers were purposively selected from the Baghpat district in Uttar Pradesh, as ICAR-IARI has adopted some of the villages, lot of interventions has been undertaken with respect to sensitizing and creating awareness about nutrition and agriculture linkages. In particular, so many biofortified varieties have been demonstrated including PM 30 (Biofortified mustard variety) which was the target variety for our analysis. The Basi, Sunehra and Lahchauda villages from Kekra block were purposively selected. From each village, the survey has been continued till minimum 20 respondents those who are aware about biofortification. In total, 134 and 123 individuals from the urban and rural area were interviewed. The survey was undertaken with a total sample size of 257 individuals.

Table 3.1 Demographic profile of the study area

Study area	Urban area	Rural area		
	NCT of Delhi	Sunehra	Basi	Lahchauda
Population	1,63,68,899	5,779	6,958	2,539
Number of Households	33,56,425	952	1,146	411
Literacy rate (%)	80.8	68	66.3	68.6
Working population (%)	33.8	30.6	40.3	37.9

3.3 Methodology and analytical techniques

3.3.1 To study the status of the biofortified varieties in India

All the biofortified varieties which are released in India along with their year of release, micronutrient content, productivity, adaptation and place of development was presented in the tabular form. By using breeder seed indent, the area covered under biofortified varieties were estimated by considering seed multiplication rate, seed rate and seed yield. The quantity of certified seeds and then the area covered by biofortified varieties was calculated by using the following data (Table 3.2) on seed rate, seed multiplication ratio, and seed yield and the same was presented in the tabular form.

Table 3.2 Crops with their seed rate, seed yield, and seed multiplication ratio

Crop	Seed Multiplication Ratio	Type	Seed rate kg/ha	Seed yield qtl/ha
Wheat	1:20		100	20
Paddy	1:80	(Varieties)	30	25
Maize	1:80	(Varieties)	20	16
	1:100	(Hybrids)		
Sorghum	1:100		12	12
Lentil	1:30		25	8
Bajra	1:200		5	10
Mustard and rape	1:100		5	5
Potato	1:4		3,000	125

Source: Seed net portal

The tabular analysis was done to know the incremental micronutrient content with the introduction of biofortified varieties for each crop and the micronutrient content in conventional crop-varieties and biofortified varieties were presented both in tabular and graphical form.

3.3.2 Cost of development of selected ICAR-IARI biofortified varieties and quantification of ex-ante health benefits

3.3.2.1 Cost of development of selected IARI biofortified varieties

The cost of development of the following ICAR-IARI biofortified (Table 3.3) was calculated by adopting Dreher *et al.* (2003) and Brennan and Martin (2005) studies, the detailed cost structure was prepared. The costs were estimated for each operation and inputs used while developing a variety. The cost of germplasm, institutional cost and cost of failure was taken as 10, 15 and 25 % of the total cost. Then the number of years a variety took for development and each year various quantity used were compiled such as material inputs, manpower such as scientific, technical, administrative, labor, etc. and then multiplied with their current price to get the actual cost and then fixed costs such as land rent depreciation some fixed costs associated crop group for R & D was apportioned based on the number of varieties developed during that period. Apart from this, the cost of cultivation techniques was employed for working the on-farm trials and multi-location trail conducted in each year. The amount spent on various years were converted into 2018-19 price. The study also focused on any extra efforts involved in introducing any particular biofortified traits into a variety in comparison to non-biofortified variety.

Table 3.3 ICAR-IARI biofortified varieties

SL. NO	ICAR-IARI Varieties	Micronutrient Content	Year of release
1.	Maize Pusa Vivek QPM9 Improved	provitamin-A (8.15 ppm), lysine (2.67%) and tryptophan (0.74%)	2017
2.	Lentil Pusa Ageti Masoor	Iron (65.0 ppm)	2017
3.	Mustard Pusa Mustard 30	low erucic acid (<2.0%)	2013
4.	Cauliflower Pusa Beta Kesari 1	β-carotene (8.0-10.0 ppm)	2015

3.3.2.2 Quantification of ex-ante health benefits

The tabular analysis was done to quantify the ex-ante health benefits by adopting *Nirmala et al. (2016)*, *Stein et al. (2008)*, *Rao et al. (2006)* and *Karim et al. (2018)* studies, the following parameters were estimated.

1. Per-capita per day micronutrient consumption
2. Per-capita per day monetary gain
3. Disability–Adjusted Life Years (DALY) method

3.3.2.2.1 Per-capita per day micronutrient consumption

Micronutrient consumption person⁻¹ day⁻¹ = (Food grain consumption person⁻¹ day⁻¹ × Micronutrient availability in food grain)

Food grain consumption person⁻¹day⁻¹ was calculated for both urban and rural areas of each state and in all India level by using monthly per capita quantity of consumption of selected commodities. The required data were collected from Household Consumption of Various goods and services and Level and pattern of consumer expenditure of 68th National Sample Survey. Micronutrient availability in food grain for both conventional crop-varieties and biofortified varieties were collected from ICAR-IARI, ICRISAT, Harvest Plus, and AICRP report.

3.3.2.2.2 Per-capita per day monetary gain from biofortified varieties

Per-capita per day monetary gain = \sum (Food grain consumption person⁻¹day⁻¹ × Change in micronutrient gain person⁻¹day⁻¹ × unit cost of particular micronutrient)

Change in micronutrient gain person⁻¹day⁻¹ was calculated by taking the difference of micronutrient content of biofortified varieties and conventional crop-varieties. The unit cost of particular micronutrient intake for each selected crop was calculated by taking the retail prices of essential commodities from Directorate of Economics and Statistics (DES). The monetary gain in rupees for selected crops was calculated by the given formula:

1. The monetary gain in Rs per capita/month = (Per capita /day monetary gain × 30)
2. The monetary gain in Rs per capita/year = (Per capita /day monetary gain × 30 × 12)
3. The total monetary gain in Rs = (Per capita per day/monetary gain × 30 × 12 × Total population)

3.3.2.2.3 Disability–Adjusted Life Years (DALY) method

The DALY method provides a single index with which to measure the morbidity and mortality related to a particular disease, and thus the burden of the disease. DALYs lost are, therefore, related to the sum of the “years of life lost” (YLL) due to cause-specific mortality and the sum of the “years lived with disability” (YLD). Then, the DALYs that are lost due to disease are:

$$\text{DALYs lost} = \text{YLL} + \text{YLD}$$

Where the sum of the DALYs lost for each disability gives the total burden of disease. Taking account of different levels of severity and of the varying extent of disease among groups within a population.

$$\text{DALYs lost} = \sum_j T_j M_j \frac{(1-e^{-rL_j})}{r} + \sum_i \sum_j T_j I_{ij} D_{ij} \left(\frac{1-e^{-rd_{ij}}}{r} \right)$$

Where,

T_j = Total number of people in the target group j

M_j = Mortality rates associated with target group j deficiency

L_j = Average life expectancy left for target group j

I_{ij} = Incidence rate of disease i in target group j

D_{ij} = Disability weight for disease i in target group j

d_{ij} = Duration of disease i in target group j (for permanent diseases d_{ij} equals the average remaining life expectancy L_j)

r = Discount rate for future life years

3.3.3 To study the perception of stakeholders about the biofortified variety and willingness to pay by consumers

3.3.3.1 Demographic details

Socio-demographic data such as age, gender, number of years of education, occupation, monthly income, household size, location, food habits, decision maker in purchasing food items were collected from a direct interview by using pre-tested schedule. Summary of socio-demographic characteristics of the respondents such as gender, occupation, decision maker in purchasing food items of both urban and rural areas are presented in tabular and graphical form.

3.3.3.2 Stakeholders awareness regarding biofortification

Knowledge index

For each respondent, the knowledge index was calculated based on their awareness regarding biofortification. Awareness scores were calculated by giving one for the right answer and zero for the wrong answer and in total six questions were asked in which each respondents score ranged from 0 to 6. The scores were categorized into four groups viz., not aware, slightly aware, moderately aware and completely aware (Kale *et al.*, 2016)

Not aware = 0

Slightly aware = Index < Mean - 1/2 Standard deviation

Moderately aware = Mean - 1/2 Standard deviation < Index < Mean + 1/2 Standard deviation

Completely aware = Index > Mean + 1/2 Standard deviation

3.3.3.3 Determinants of stakeholders' awareness of biofortification

The awareness of stakeholders regarding biofortification relies not only on the perception but also on several socio-economic and demographic factors. Binary logit model has therefore been used to define the variables that determine stakeholder' awareness since the dependent variable is discrete. Biofortification awareness can be modelled as a choice between two alternatives, aware or not aware. If the respondent was aware, the binary random variable Y_i takes the value of 1 and zero otherwise,

The Logit model postulates that P_i is a function of an index variable Z_i , Z_i is equal to the logarithm of the odds ratio, i.e., ratio of probability that a stakeholder is aware to the probability that he is not aware and it can be estimated as a linear function of explanatory variables (X_{ki}). Mathematically it is given below,

$$P_i = F(Z_i) = F(X_i) = 1 / (1 + e^{-Z_i})$$

$$Z_i = \ln \left\{ \frac{P_i}{1 - P_i} \right\} = \alpha + \sum_{k=1}^M \beta_k X_{ki}$$

Where, $i = 1, 2, \dots, N$ and N is the total number of respondents,

X = explanatory variable (age in years, gender, number of years of education, occupation, monthly income, household size, location, food habits, decision maker in purchasing food items),

$k = 1, 2 \dots M$. and M is the total number of explanatory variables,
 α = Constant and
 β = Unknown parameter.

Additionally, marginal effects were estimated to measure instantaneous effects of changes in any independent variable on the predicted probability of being aware, while holding other independent variables constant.

The binary logit model and marginal effects were estimated using the statistical package STATA, version 12. It has been hypothesized that as the age increases, the awareness of the respondent tends to decrease. Respondents having higher education with the greater income tends to have higher awareness. Female respondents were generally more aware than the male. It was anticipated that education and income would have a positive impact.

3.3.3.4 Sources of information regarding biofortification

The respondents were given with the following sources viz., radio, newspaper, television, internet, journals, articles, exhibitions, trainings, friends, relatives, and others to specify and asked them to tick as many as so that difference in extent of sources from where they had got information regarding biofortification was analyzed for both urban and rural area. Comparisons were made by using tabular and graphical form.

3.3.3.4 Stakeholders perception regarding biofortified products

It is important to study the perception of respondents, because the perception of health benefits, taste, convenience, and other attributes affect the decision to buy products and the decision of quantity to consume was affected by perceptions and knowledge (Moon and Balasubramanian, 2002). Therefore, this study was aimed to explore stakeholder's perception of biofortification.

Likert Scale

Since the data on perception was qualitative, we had chosen Likert-scale (1 to 5) and analysed the responses and presented in the form of %ages by using the bar chart. The response continuum for each statement is a linear scale which indicated the extent of respondents agree or disagree with each statement. In total 5 statements were given in the schedule and the scores on the schedules are on a Likert scale viz., Strongly disagree=1, Disagree=2, Undecided/No opinion=3, Agree=4, Strongly agree=5.

3.3.3.5 Consumers' food purchasing behavior

The study collected three types of data concerning respondent purchasing behavior. Respondents were first asked about their frequency of purchasing of newly arrived food products in the market (always/ often/ sometimes/ rarely/ never), buying behavior of the biofortified product if it were available in the supermarket (yes/no) and opinion regarding the requirement of promotion and advertisements for the biofortified product for wider adoption (Yes/No), then tabular analysis was done to know the % age of respondent's accounts for each closed-ended class.

3.3.3.6 Factors influencing food purchase

Acceptance of a new product by consumers depends on several factors which influence a person's decision to purchase or to consume a food product. Therefore, purchasing a food product depend on the choice behavior of individual respondents who consume particular products. The major factors that influence the purchase of food product are listed in the schedule and each respondent was asked to rate five product characteristics viz., price, taste, nutrition, brand, and additional health ingredients according to the level of importance in influencing their food purchase. The rating was based on a five-point Likert scale for each characteristic, which includes not at all important (1), slightly important (2), moderately important (3), important (4), and very important (5) and presented the %age preference to each factor using bar diagram.

3.3.3.7 Willingness to pay (WTP) for the biofortified product

3.3.3.7.1 Test of the randomness of initial bids

It was done by tabulating the initial bid to see if different initial bids are represented equally in the data on average.

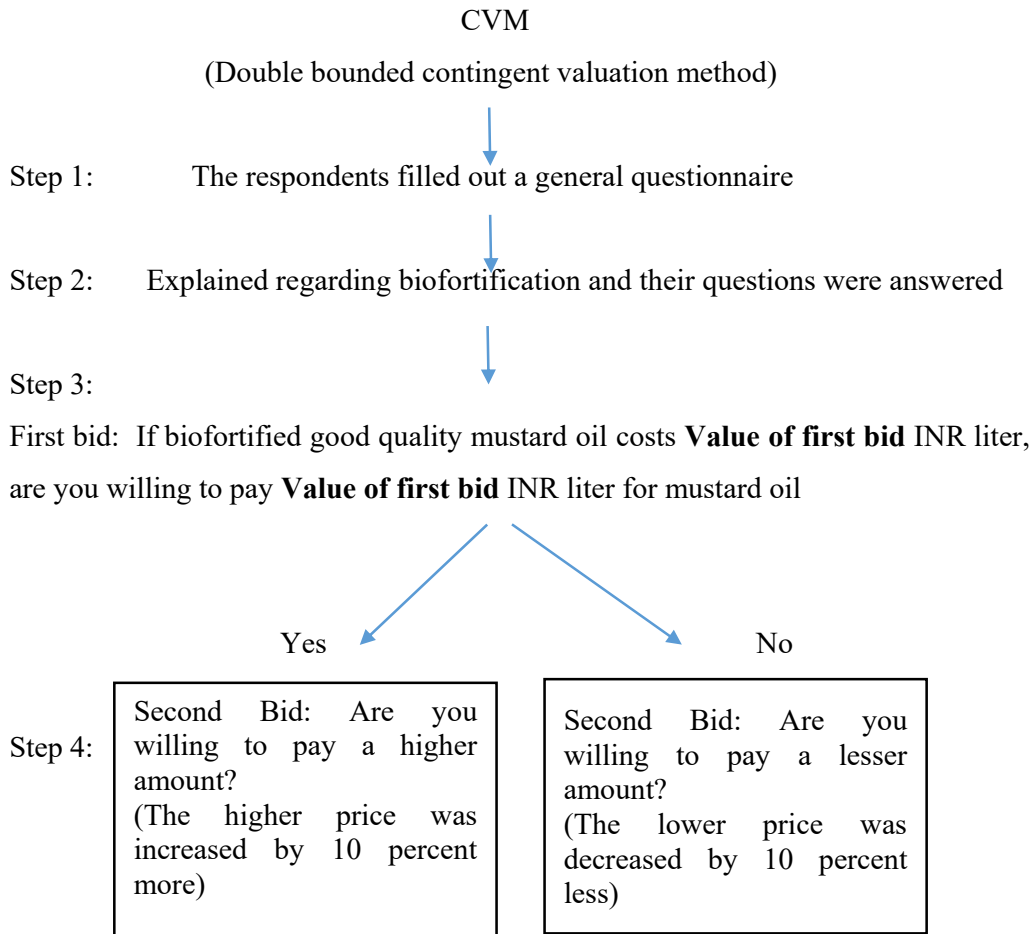
3.3.3.7.2 Price test

There were two ways to tabulate the bid values with a proportion of yes or no answers for the first bid. By rule, as the bid value increases, the proportion of no response should increase as per the law of demand.

3.3.3.7.3 Double Bound Contingent Valuation Method

Contingent valuation method (CVM) was used to calculate the consumers' willingness to pay for each attribute of the product. Here, every individual

(respondent) was confronted with two bids and in the first bid, the respondent was asked whether he was willing to pay a particular amount for a good. Based on his response, a second bid was offered. If the respondent answer was yes, then a second bid with a higher amount was offered and if the answer was no, then a second bid with a lower amount was offered.



WTP, without control

Gives the WTP value directly in case where no control variables are used.

WTP, with controls

The control variables used in the study were age, gender, number of years of education, occupation, monthly income, household size, location, and food habits. WTP was calculated for mean values of the control variables using Double Bound Contingent Valuation which directly gives the value of WTP.

3.3.3.7.4 Determinants of WTP

The value of WTP was estimated for each respondent and then regressed on the explanatory variables to know how these variables affect WTP. The explanatory variables used in the study were age, gender, number of years of education, occupation, monthly income, household size, location, and food habits.

RESULTS

The results were presented in three sections based on the objectives. The status of the biofortified varieties in India along with their area and share was presented in the first section. The cost of development of selected IARI biofortified varieties and of ex-ante health benefits were discussed in the second section. The third section deals with the awareness and perception study of stakeholders about the biofortified variety and willingness to pay a premium price for biofortified products by consumers.

4.1 Status of the biofortified varieties in India

The biofortified varieties of cereals, oilseeds, vegetables and fruits which were released in India till 2017 were presented in Table 4.1 along with their year of release of variety, micronutrient content in both biofortified and conventional varieties, grain yield, recommended area and institution involved in the development of the variety.

The cereals, vegetables, fruits have been biofortified to improve its zinc, iron, protein, amino acids, anthocyanin, β -carotene, vitamin C content in the crop whereas in oilseeds, biofortification was done to decrease the erucic acid and glucosylates content in oilseeds. Out of 19 biofortified varieties, 12 varieties were from cereals and 1 from pulses, 4 fruits and vegetables and 2 from oilseeds. The 14 varieties were developed by ICAR institutes, 2 from CGIAR institute (ICRISAT) and 3 were from SAUs.

Table 4.1. Biofortified varieties released in India

Biofortified Varieties	Year of release	Nutrient	Nutrient content		Grain Yield (q/ha)	Adaptation	Institution which developed the variety	
			Biofortified Varieties	Popular varieties				
Rice Varieties								
1. CR 310	Dhan	2016	Protein	10.3	7.0-8.0	45	Odisha, Madhya Pradesh and Uttar Pradesh	ICAR-National Rice Research Institute, Cuttack, Odisha
2. DRR 45	Dhan	2016	Zinc	2.26	1.2-1.6	50	Karnataka, Tamil Nadu, Andhra Pradesh and Telangana	ICAR-Indian Institute of Rice Research, Hyderabad
Wheat Varieties								
3. WB 02		2017	Zinc Iron	4.2 4	3.2 2.8-3.2	51.6	Punjab, Haryana, Delhi, Rajasthan, Western UP, Jammu and Kashmir, HP and Uttarakhand	ICAR-Indian Institute of Wheat and Barley Research, Karnal
4. HPBW 01		2017	Zinc Iron	4.06 4	3.2 2.8-3.2	51.7	Punjab, Haryana, Delhi, Rajasthan, Western UP, Jammu & Kashmir, HP and Uttarakhand	Punjab Agricultural University, Ludhiana under ICAR-AICRP on Wheat & Barley
Maize Varieties								
5. Pusa Vivek QPM9 Improved		2017	Tryptophan Lysine Provitamin-A	0.74 2.67 8.15	0.3-0.4 1.5-2.0 1.0-2.0	55.9	J&K, Himachal Pradesh, Uttarakhand, North Eastern states, Maharashtra, Karnataka, AP, Telangana and Tamil Nadu	ICAR-Indian Agricultural Research Institute, New Delhi

Biofortified Varieties	Year of release	Nutrient	Nutrient content		Grain Yield (q/ha)	Adaptation	Place of development
			Biofortified Varieties	Popular varieties			
6. Pusa HM4 Improved	2017	Tryptophan Lysine	0.91 3.62	0.3-0.4 1.5-2.0	64.2	Punjab, Haryana, Delhi, Uttarakhand, Uttar Pradesh	ICAR-Indian Agricultural Research Institute, New Delhi
7. Pusa HM8 Improved	2017	Tryptophan Lysine	1.06 4.18	0.3-0.4 1.5-2.0	62.6	Maharashtra, Karnataka, Andhra Pradesh, Telangana, Tamil Nadu	ICAR-Indian Agricultural Research Institute, New Delhi
8. Pusa HM9 Improved	2017	Tryptophan Lysine	0.68 2.97	0.3-0.4 1.5-2.0	52	Bihar, Jharkhand, Odisha, Uttar Pradesh and West Bengal	ICAR-Indian Agricultural Research Institute, New Delhi
Pearl millet Varieties							
9. HHB 299	2017	Zinc Iron	4.1 7.3	3-3.5 4.5-5	32.7	Haryana, Rajasthan, Gujarat, Punjab, Delhi, Maharashtra and Tamil Nadu	CCS-Haryana Agricultural University, Hisar in collaboration with ICRISAT, Patancheru under ICAR-AICRP on Pearl millet
10. AHB 1200	2017	Iron	7.3	4.5-5	32	Haryana, Rajasthan, Gujarat, Punjab, Delhi, Maharashtra and Tamil Nadu	Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (MS) in collaboration with ICRISAT, Patancheru under ICAR-AICRP on Pearl millet
11. ICTP 8203	2013	Iron	7.1	4.5-5	21.99	Maharashtra and Andhra Pradesh	International Crops Research Institute for the Semi-Arid Tropics

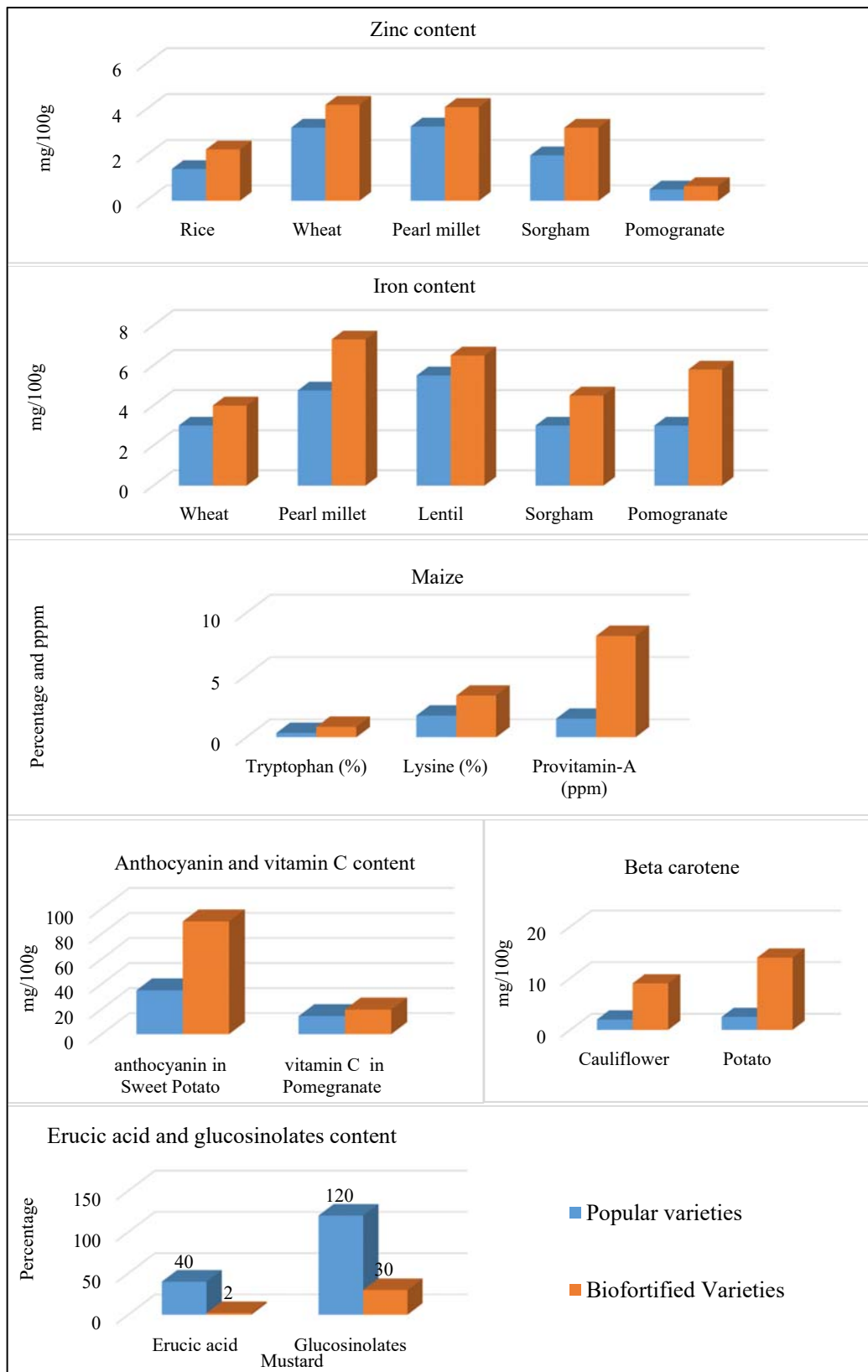
Biofortified Varieties	Year of release	Nutrient	Nutrient content		Grain Yield (q/ha)	Adaptation	Place of development
			Biofortified Varieties	Popular varieties			
Sorghum variety							
12. ICSR 14001 (Parbhani Shakti)	2018	Zinc	3.2	2	5	Maharashtra	International Crops Research Institute for the Semi-Arid Tropics
Lentil Variety							
13. Pusa Ageti Masoor	2017	Iron	6.5	5.5	13	Utter Pradesh, Madhya Pradesh, Chhattisgarh	ICAR-Indian Agricultural Research Institute, New Delhi
Mustard Varieties							
14. Pusa Mustard 30	2013	Erucic acid	<2.0	>40	18.2	Utter Pradesh, Uttarakhand, Madhya Pradesh and Rajasthan	ICAR-Indian Agricultural Research Institute, New Delhi
15. Pusa Double Zero Mustard 31	2016	Erucic acid	<2.0	>40	23	Rajasthan, Punjab, Haryana, Delhi, Western UP, J&K and HP	ICAR-Indian Agricultural Research Institute, New Delhi
Cauliflower Variety							
16. Pusa Beta Kesari 1	2015	β -carotene	0.8-10	2	40.0-50	Nation Capital Region of Delhi	ICAR-Indian Agricultural Research Institute, New Delhi

Biofortified Varieties	Year of release	Nutrient	Nutrient content		Grain Yield (q/ha)	Adaptation	Place of development
			Biofortified Varieties	Popular varieties			
Potato Variety							
17. Bhu Sona	2017	β -carotene	14	2.0-3.0	19.8	Odisha	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala
Sweet potato Variety							
18. Bhu Krishna	2017	Anthocyanin	90	25-50	18	Odisha	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala
Pomegranate Variety							
19. Solapur Lal	2017	Iron zinc vitamin C	5.6-6.1 0.64-0.69 19.4 -19.8	2.7-3.2 0.50-0.54 14.2-14.6	23-27	Semi-arid regions of the country	ICAR-National Research Centre on Pomegranate, Pune

Note: Iron, Zinc, β -carotene, anthocyanin, vitamin C in mg/100g, Protein, Tryptophan, Lysine, Erucic acid in percentage (%), Provitamin-A in ppm

Source: ICAR Biofortified varieties and Harvest Plus

Figure 4.1 Micronutrients availability in conventional and biofortified varieties



Micronutrient content in all the biofortified varieties were more than that of the conventional varieties except for mustard (Fig. 4.1) in which erucic acid and glucosinolates content in biofortified varieties were less than the normal varieties (less acid content was healthier).

Table 4.2, presents the crop-wise share of biofortified varieties in India. In total, biofortification was done in eleven crops in which the cereals had the highest share (61.9 %) followed by vegetables with three varieties which accounts for 23.81 %. Subsequently, the oilseeds and fruits which accounted for 9.52 % and 4.76 % respectively.

Table 4.2 Crop-wise biofortified varieties and their shares in total biofortified varieties

Crops wise biofortified varieties		Percentage Share
Crop	Number of crops	
Cereals		
(a) Rice	2	
(b) Wheat	2	
(c) Maize	4	
(d) Pearl millet	3	
(e) Sorghum	1	
(f) Lentil	1	
Subtotal	13	61.90
Oilseeds		
(a) Mustard	2	9.52
Vegetables		
(a) Potato	1	
(b) Cauliflower	1	
(c) Sweet potato	1	
Subtotal	5	23.81
Fruits		
(a) Pomegranate	1	4.76
Total	21	100

From the Table 4.3, it can be seen that biofortified bajra occupied the highest percentage of the area (32 %) among all the biofortified crops and is dominated by

Dhanashakti and its area coverage was 2.36 mha. Paddy covered the next highest area under biofortified crop variety CRR DHAN-310 and DRR Dhan-45, in total it has covered about 1.1 mha. Mustard occupied the third highest area under biofortified crops with 0.418 mha, followed by lentil (Pusa Ageti Masoor) and wheat occupied an area of 0.08 mha and 0.04 mha, respectively.

Table 4.3 Extent of adoption of biofortified varieties

Crops	Varieties	Area ('000 Hectares)		
		All India crop coverage (TE 2016-17)	The total estimated area in biofortified crops	Share of biofortified variety (%)
1. Wheat	WB-2*, HPBW-01*	30,889.53	4.48	0.02
2. Paddy	CRR Dhan 310, DRR Dhan-45	43,867.7	1,129.6	2.58
3. Lentil	Pusa Ageti Masoor*	1,401.9	81.9	5.84
4. Bajra	Dhanshakti, HHB-299*, AHB-1200*	7,301.7	2,360.0	32.32
5. Mustard and rape	Pusa Mustard 30, Pusa Double Zero Mustard 31*	6,020.0	418.0	6.94

* Varieties seed indent was taken from 2018-19

4.2 Analyzing the cost of development of selected IARI biofortified varieties and quantification of ex-ante health benefits

4.2.1 Cost of development of selected IARI biofortified crops

In this study, the cost of development of four crops viz., maize, lentil, mustard and cauliflower were calculated by compiling information from the respective breeder of the crops which includes laboratory expenses, field costs, cost of human capital, cost of germplasm, cost of failure and institutional overhead charges.

4.2.1.1. Maize

The cost of varietal development was about Rs 2.9 crores out of which the field and laboratory cost (please refer annexures for details) incurred was 100.68 lakh rupees which accounted for the highest share (34.53 %), followed by the human capital which

had the share of 32 % (Table 4.4). The cost of cultivation was compiled from Directorate of Economic and Statistics for one hectare from which the cost of cultivation for the actual area used for varietal development was calculated and multiplied with the number of years required for the breeding programme. While calculating the cost of cultivation, 50 % additional cost was taken since the breeding involves much care and attention. In total, the cost of cultivation accounted for Rs 4,692.6 for the research field. The institutional overhead charge was assumed about 10 % of the human capital costs and field and lab expenditures. Similarly, the cost of failure of research was assumed to be 25 %.

Table 4.4 Total cost of development of maize

Cost components	Total costs (in lakh rupees)	Scenarios	
		25% decrease in cost	25 % increase in cost
(a) Human capital			
Scientist	55.89	41.92	69.86
Technical Assistant	12.60	9.45	15.75
Supporting staff	10.80	8.10	13.50
Skilled Labours	14.40	10.80	18.00
Sub-total (a)	93.69	70.27	117.11
% Share	32.13	32.13	32.13
(b) Field and laboratory cost			
MLT	1.90	1.42	2.37
Cost of cultivation	0.05	0.04	0.06
Lab expenditures	98.74	74.06	123.43
Sub-total (b)	100.68	75.51	125.85
% Share	34.53	34.53	34.53
(c) Institutional overhead costs			
% Share	10.00	10.00	10.00
Sub-total (a+b+c)	223.53	167.65	279.41
% Share	76.67	76.67	76.67
(d) Cost of germplasm			
% Share	19.44	14.58	24.30
% Share	6.67	6.67	6.67
(e) Cost of failure			
% Share	48.59	36.44	60.74
% Share	16.67	16.67	16.67
Total	291.56	218.67	364.45

The actual cost of development of variety and two scenarios of 25 % decrease and 25 % increase in the cost was estimated to account all the over estimated costs and

under estimated costs (intangible costs which were not taken during the accounting). The actual cost accounts for 291.56 lakh rupees and the costs of 25 % decrease and increase in the costs account for 218.67 and 364.45 lakh rupees, respectively.

4.3.1.2 Lentil

Out of the total cost of development of lentil, the total cost of cultivation accounted for 1.52 lakh rupees for the 8 years. Human capital, which accounted for 196.42 lakh rupees, occupied a major share in total cost (59.87 %). The actual cost of development accounted for 328.05 lakh rupees and in two scenarios of a 25 % decrease and increase in the cost's accounts for 246.04 and 410.07 lakh rupees respectively (Table 4.5).

Table 4.5 Total cost of development of lentil

Cost components	Total costs	Scenarios	
		25 % decrease in cost	25 % increase in cost
(a) Human capital			
Scientist	147.46	110.59	184.32
Technical Assistant	20.16	15.12	25.20
Supporting staff	11.52	8.64	14.40
Skilled labour	17.28	12.96	21.60
Sub-total (a)	196.42	147.31	245.52
% Share	59.87	59.87	59.87
(b) Field and laboratory cost			
MLT	0.76	0.57	0.95
Cost of cultivation	1.52	1.14	1.91
Lab expenditures	20.00	15.00	25.00
Sub-total (b)	22.29	16.71	27.86
% Share	6.79	6.79	6.79
(c) Institutional overhead costs			
% Share	10.00	10.00	10.00
Sub-total (a+b+c)	251.51	188.63	314.38
% Share	76.67	76.67	76.67
(d) Cost of germplasm			
% Share	6.67	6.67	6.67
(e) Cost of failure			
% Share	16.67	16.67	16.67
Total	328.05	246.04	410.07

4.2.1.3 Mustard

In the estimation of the cost of development of mustard, field and laboratory expenses together accounted for 96 lakh rupees, human capital accounted for 203.31 lakh rupees and the total cost of cultivation for mustard was 6.06 lakh rupees. The actual cost of development of mustard accounted for 459.87 lakh rupees and in two scenarios of 25 percent decrease and increase in the costs accounted for 344.90 and 574.84 lakh rupees respectively (Table 4.6).

Table 4.6 Total cost of development of mustard

Cost components	Total costs (lakh rupees)	Scenarios	
		25 % decrease in cost	25 % increase in cost
(a) Human capital			
Scientist	147.63	110.72	184.54
Technical Assistant	20.16	15.12	25.20
Supporting staff	11.52	8.64	14.40
labour requirement	24.00	18.00	30.00
Sub-total (a)	203.31	152.48	254.14
% Share	44.21	44.21	44.21
(b) Field and laboratory cost			
MLT	1.21	0.91	1.52
Cost of cultivation	6.06	4.55	7.58
Field expenses	36.00	27.00	45.00
Lab expenditures	60.00	45.00	75.00
Sub-total (b)	103.27	77.45	129.09
% Share	22.46	22.46	22.46
(c) Institutional overhead costs			
	45.99	34.49	57.48
% Share	10.00	10.00	10.00
Sub-total (a+b+c)	352.57	264.43	440.71
% Share	76.67	76.67	76.67
(d) Cost of germplasm			
	30.66	22.99	38.32
% Share	6.67	6.67	6.67
(e) Cost of failure			
	76.65	57.48	95.81
% Share	16.67	16.67	16.67
Total	459.87	344.90	574.84

4.2.1.4 Cauliflower

The human capital in cauliflower breeding accounted for 167.42 lakh rupees followed by the cost of failure which accounted for 46.88 lakh rupees and the total cost of cultivation accounted for 1.85 lakh rupees a total area which was used for breeding of cauliflower). The actual cost of breeding 281.27 lakh rupees. The two scenarios of a 25 % decrease and increase in the costs accounted for 210.95 and 351.58 lakh rupees respectively (Table 4.7). Among all the four varieties, cost of breeding was lowest in this crop.

Table 4.7 Total cost of development of cauliflower

Cost components	Total costs (lakh rupees)	Scenarios	
		25 % decrease in cost	25 % increase in cost
(a) Human capital			
Scientist	110.72	83.04	138.40
Technical Assistant	15.12	11.34	18.90
SRF	28.08	21.06	35.10
Daily paid labour	10.80	8.10	13.50
Temporary Field Labour	2.70	2.03	3.38
Sub-total (a)	167.42	125.57	209.28
% Share	59.52	59.52	59.52
(b) Field and laboratory cost			
MLT	1.24	0.93	1.55
Cost of cultivation	1.85	1.39	2.32
Lab expenditures	17.00	12.75	21.25
Sub-total (b)	20.09	15.07	25.11
% Share	7.14	7.14	7.14
(c) Institutional overhead costs			
	28.13	21.10	35.16
% Share	10.00	10.00	10.00
Sub-total (a+b+c)	215.64	161.73	269.55
% Share	76.67	76.67	76.67
(d) Cost of germplasm			
	18.75	14.06	23.44
% Share	6.67	6.67	6.67
(e) Cost of failure			
	46.88	35.16	58.60
% Share	16.67	16.67	16.67
Total	281.27	210.95	351.58

The cost of development of varieties ranged from 3 crores to 4.5 crores (Table 4.8). Among four crop varieties, the cost of development of cauliflower was found to be lowest (281.27 lakh rupees) and the mustard was found to be highest (459.87 lakh rupees). Since the breeding procedure for cauliflower does not involve intensive care and while in mustard, the field level cost (cost of net and iron poles) was more while developing a variety.

Table 4.8 Summary of cost components for selected crops

Cost components	Crops			
	Maize	Lentil	Mustard	Cauliflower
(a) Human capital	93.69	196.42	203.31	167.42
% Share	40.44	62.33	44.21	59.52
(b) Field and laboratory cost	100.68	22.29	103.27	20.09
% Share	34.53	6.79	22.46	7.14
(c) Institutional overhead costs	29.16	32.81	45.99	28.13
% Share	10.00	10.00	10.00	10.00
(d) Cost of germplasm	19.44	21.87	30.66	18.75
% Share	6.67	6.67	6.67	6.67
(e) Cost of failure	48.59	54.68	76.65	46.88
% Share	16.67	16.67	16.67	16.67
Total	291.56	328.05	459.87	281.27

4.2.2 Monetary Gain

The monetary gain from the consumption of biofortified varieties were calculated by calculating the incremental micronutrient consumption and by number of years of DALY saved by the consumption of biofortified crops.

4.2.2.1 Monetary gain from incremental micronutrient consumption of zinc

Zinc content in popular and biofortified varieties was presented in Table 4.9. Among all zinc biofortified varieties, incremental zinc was found to be highest in sorghum (12 mg) followed by wheat (10 mg). The unit cost of micronutrient intake was found to be lowest in bajra (0.83 Rs/mg of Zn) followed by wheat (0.84 Rs/mg of Zn) and highest in rice (2.29 Rs/mg of Zn).

Table 4.9 Estimated Zn content and unit cost of Zn (Rs/mg)

	Crops			
	Rice	Wheat	Bajra	Sorghum
Popular varieties (Zinc mg/Kg)	14	32	32.5	20
Biofortified Varieties (Zinc mg/Kg)	22.6	42	41	32
Zn increment (mg)	8.6	10	8.5	12
Rupees/ kg of commodity	32	27	27	31
Unit cost of micronutrient intake (Rs/ mg of Zn) in commodities	2.29	0.84	0.83	1.55

Source: ICAR Biofortified varieties, Harvest plus, DES

Table 4.10 shows the quantity of monthly per capita consumption, incremental zinc intake and monetary gain in various zinc biofortified varieties. Among all commodities, monthly rice consumption (5.39 kg) and incremental zinc intake from rice (46.36 mg/month) were found to be highest followed by monthly wheat consumption (4.39 kg) and incremental zinc intake from wheat (43.92mg/month). In terms of monetary gain, monthly per capita gain was found to be highest in rice (Rs 105.97) followed by wheat (Rs 37.05).

Table 4.10 Estimated increment in zinc (mg) and monetary gain (Rs) from biofortified varieties

Crops	Quantity		Monitory gain			
	Monthly Per capita consumption (kg)	Incremental Zn intake (mg/month)	Monthly per capita gain (Rs)	Actual consumption (crore rupees) a	2 % of total consumption (crore rupees) b	5 % of total consumption (crore rupees) c
Rice	5.39	46.36	105.97	10547.49	3077.91	7694.77
Wheat	4.39	43.92	37.05	19.44	1076.32	2690.81
Sorghum	0.17	2.04	3.16	-	91.83	229.59
Bajra	0.17	1.43	1.18	4811.79	34.55	86.39

Note: a- Indicates actual quantity of consumption (produced) estimated based on the biofortified area coverage

b- Indicates scenario1 where it was assumed that if 2 % of total consumption of the food items were supplied by respective biofortified crops

c- Indicates scenario 2 where it is assumed that if 5 % of total consumption of the food items were supplied by respective biofortified crops

The incremental iron was found to be the highest in bajra (25.5 mg) followed by sorghum (15 mg) (Table 4.11). It was found that the unit cost of micronutrient intake was lowest in bajra (0.57 Rs/mg Fe) followed by wheat (0.9 Rs/mg Fe) and highest in lentil (1.18 Rs/mg Fe).

Table 4.11 Estimated iron content and unit cost of iron (Rs/mg)

Iron (mg/kg)	Crops			
	Wheat	Bajra	Lentil	Sorghum
Popular varieties (Fe mg/Kg)	30	47.5	55	30
Biofortified Varieties (Fe mg/Kg)	40	73	65	45
Fe increment (mg)	10	25.5	10	15
Rupees/ kg	27	27	65	31
Unit cost of nutrient intake (mg of Fe)	0.9	0.57	1.18	1.03

Source: ICAR Biofortified varieties and Harvest plus

Incremental monetary gain due to iron biofortified varieties is given in Table 4.12. Monthly per capita consumption of wheat (4.39 kg) and incremental intake of iron from wheat (43.92 mg/month) was found to be the highest followed by monthly per capita consumption of sorghum and bajra (0.17 kg) and incremental intake of iron in bajra (4.30 mg/month). In terms of monetary gain, it was found that the highest monthly per capita gain was from wheat (Rs 39.5) followed by bajra (Rs 2.44).

Table 4.12 Estimated increment in iron (mg) and monetary gain (Rs) from biofortified varieties

Crops	Quantity		Monitory gain			
	Monthly Per capita consumption (kg)	Incremental Fe intake (mg/month)	Monthly per capita gain (Rs)	Actual consumption (crore rupees)	2 % of total consumption (crore rupees)	5 % of total consumption (crore rupees)
				a	b	c
Wheat	4.39	43.92	39.5	20.83	1135.79	283947.80
Sorghum	0.17	0.001	0.0030	-	0.07	0.18
Bajra	0.17	4.30	2.44	9913.45	38.31	95.77
Masur	0.10	1.02	1.048	125.67	27.31	68.27

Note: As mentioned in Table 4.10

Table 4.13 Estimated amino acids content and unit cost of amino acids in maize (Rs/mg)

	Tryptophan (%)	Lysine (%)	Provitamin-A (ppm)
Popular varieties	0.35	1.75	1.5
Biofortified Varieties	0.85	3.36	8.15
Increment (mg)	0.50	1.61	6.65
Rupees/ kg	26	26	26
Unit cost of nutrient intake(Rs)	74.29	14.86	17.33

Source: ICAR Biofortified varieties, Harvest plus and DES

The average monthly per capita consumption of maize in India was 0.0775 kg. The highest increment from maize consumption was seen in provitamin-A (5.15 mg/month) and also the monthly per capita gain of Rs 8.93 followed by tryptophan and lysine (Table 4.14)

Table 4.14 Estimated increment in amino acids (mg) and monetary gain (Rs) from biofortified varieties

Crop-Maize	Quantity		Monitory gain		
	Monthly Per capita consumption (kg)	Incremental amino acids intake (mg/month)	Monthly per capita gain (Rs)	2 % of total consumption (crore rupees)	5 % of total consumption (crore rupees)
Tryptophan (mg)	0.0775	0.38	2.86	83.19	207.97
Lysine (mg)		1.25	1.85	53.84	134.60
Provitamin-A (mg)		5.15	8.93	259.46	648.65

Note: As mentioned in Table 4.10

The average monthly per capita consumption of potato in India was 1.79kg with the average micronutrient content of 2.5 mg/kg. From Table 4.15 and 4.16, the unit cost and monthly per capita gain from β -carotene intake was found to be Rs 0.72 and Rs 14.81 respectively.

Table 4.15 Estimated β -carotene content and unit cost of β -carotene in potato (Rs/mg)

Potato	β -carotene (mg)
Popular varieties	2.5
Biofortified Varieties	14
Increment (mg)	11.5
Rupees/kg	18
The unit cost of nutrient intake (Rs)	0.72

Source: ICAR Biofortified varieties, Harvest plus, DES

Table 4.16 Estimated increment in amino acids (mg) and monetary gain (Rs) from biofortified varieties

S. No	Crop- Potato	Quantity		Monetary Gain		
		Monthly Per capita consumption (kg)	Incremental β - carotene intake (mg/month)	Monthly per capita gain (Rs)	2 % of total consumption (crore rupees) b	5 % of total consumption (crore rupees) c
1	Tryptophan (mg)	1.7885	20.57	14.81	430.12	1075.29

Note: As mentioned in Table 4.10

In this study, the widely used Disability-Adjusted Life Year (DALY) approach was used to assess the current burden of zinc deficiency in India and also to determine the potential health benefits from the intervention of biofortification. Table 4.17 presents the results of DALYs lost due to zinc deficiency in India in both pessimistic (without the use of biofortified varieties) and in optimistic (with use of biofortified varieties) ways. While calculating DALYs lost, whole India was divided into four regions such as rice and wheat consuming states (states where consumption of rice and wheat is more than 80 % in total consumption), rice-wheat consuming states (each with more than 30% of consumption) and rice-wheat millet consuming states (each with more than 15 % of consumption) . It was showed that per capita DALY lost was highest in wheat consuming region (0.103) and in all India, the DALY lost was 0.102. In the optimistic scenario, the DALYs lost was less when compared with the pessimistic scenario due to the use of biofortified varieties. In an optimistic scenario, the per capita DALYs lost was highest in wheat consuming region (0.071) and lowest in rice- wheat-millet consuming region (0.065) with all India average per capita DALY lost was found to be 0.068.

In pessimistic scenario, the per capita DALY lost in monetary terms was found to be highest in wheat consuming region (Rs 8,906.01) and in all India average found to be Rs 8,836.743 and in an optimistic scenario, highest per capita DALY lost was found in wheat consuming region (Rs 6,120) where all India average of Rs 5,902.80. The gain from biofortification in terms of DALY was arrived by taking the difference between the optimistic and pessimistic scenario. As per the above table, the per capita DALY and monetary gain were found to be highest in the rice-wheat-millet region (0.0374) and with all India average monetary gain of Rs 2,933.94. Overall the total disease burden saved by zinc biofortification accounts for Rs. 455 bn.

Table 4.17 Extent of DALY lost in pessimistic and optimistic scenario of Zinc bio-fortification

Pessimistic			
Regions	DALY lost (million years)	Per capita DALY lost (years)	Per capita DALY lost (monetary terms in Rs) (@per capita NI) (Rs.)
Rice	0.4849	0.102	8,871.83
Wheat	0.1490	0.103	8,906.01
Rice-Wheat	0.6071	0.100	8,702.22
Rice-Wheat-Millet	0.3393	0.102	8,866.92
All India	1.5803	0.102	8,836.74
Optimistic (Use of biofortified varieties)			
Rice	0.3255	0.069	5,954.15
Wheat	0.1024	0.071	6,120.00
Rice-Wheat	0.4127	0.068	5,913.86
Rice-Wheat-Millet	0.2151	0.065	5,623.19
All India	1.0556	0.068	5,902.80
Gain from biofortification			
Regions	DALY gain (million years)	Per capita DALY gain (years)	Per capita DALY gain (monetary terms) (@per capita NI) (Rs.)
Rice	0.1595	0.0337	2917.68
Wheat	0.0467	0.0321	2786.01
Rice-Wheat	0.1945	0.0322	2788.36
Rice-Wheat-Millet	0.1241	0.0374	3243.73
All India	0.1595	0.0339	2933.94

4.3 The perception of stakeholders about the biofortified variety and willingness to pay by consumers

This objective study the following aspects of the respondents viz., Socio-demographic characteristics of the respondents, Stakeholders awareness regarding biofortification, Stakeholders perception regarding biofortified products, stakeholder's food purchasing behavior and Willingness to pay for the biofortified product.

4.3.1 Socio-demographic characteristics of the respondents

The socio-demographic characteristics of the sample respondents are presented in Table 4.18. The number of respondents in the urban and rural study area were 134 and 123 respectively. The respondents average age was found to be 36.4 years in urban and 41.1 years in a rural area which varied from 15 to 88 years, persons younger than 15 years were not selected for the interviews as it was assumed that the younger children had less experience in shopping and would give biased responses. The average monthly household income was approximately Rs. 52,300 in urban and Rs. 16,300 in a rural area. The average household size in the sample was 5.23 (5) in which average household size was more in rural (6.45) than in urban (4.11). The mean number of years of formal education of the respondents found to be 11.66, with 32.43 % of the respondents having a secondary education.

Table.4.18 Socio- demographic profile of the respondents

	Urban	Rural	Total
Number of respondents	134	123	257
Average age of respondent (years)	36.40	41.10	38.75
Average household income (INR)	52,300	16,300	34,300
Average household size	4.11	6.45	5.23
Level of education (%)			
Illiterate	0.75	21.95	11.35
Primary	6.72	16.26	11.49
Secondary	20.15	44.72	32.43
Diploma / Bachelor degree	37.31	15.45	26.38
Other (MSc, PhD)	35.07	1.63	18.35
Gender of respondent (% Female)	45.00	51.00	48.00
Aware of biofortification (% Yes)	44.78	49.59	47.18

The number of female respondents was high in rural (51 %) than in urban area (45 %) because individuals in the study areas were selected based on availability and responsibility for food purchase in the household. In total, the tabular analysis showed that 49.59 % of the rural respondents and 44.78 % of the urban respondents were aware

of biofortification. Specifically, indicate that rural consumers have higher levels of awareness on biofortification than urban consumers. However, it was to be noted that rural consumers have purposively chosen from the ICAR-IARI adopted villages, so it cannot be generalized.

Table 4.19 depicted the occupation of the respondents. The urban respondent's occupation majorly comprises of salaried employment (66 %) and non-agricultural enterprises (25 %). Whereas, in the case of rural areas, agriculture (53 %), agriculture along with wage employment (13) and agriculture along with agriculture labour were the main occupations.

Table 4.19 Occupation of the respondents

	Occupation	Urban (%)	Rural (%)
1.	Agriculture	1.49	52.85
2.	Agricultural labour	0.00	10.57
3.	Wage/Salaried employment	66.42	1.63
4.	Non-agricultural enterprises	25.37	0.81
5.	Agriculture + Agricultural labour	0	8.94
6.	Agriculture + wage/salaried employment	0	13.01
7.	Pensioners	2.24	0.00
8.	Others	4.48	13.00

The food items purchase, especially vegetables will be influenced by the kids or husbands and sometimes the maid's choices. Therefore, it was important to know who was responsible for taking decisions regarding the purchase of food items. Further, some purchases according to the ease of purchase, their shopping experience, advertisements, and some are particular (conservative) and servants who mainly decide based on his or her job commitment. Therefore, the decision makers were classified into husband, wife, children, elders, servants and others in Fig. 4.2, the decision maker would be important if the impact of nutritious foods on public health was to be realized. The results showed that 74 % of the wives in an urban area and 56 % of the husband in rural were the major decision maker in purchasing food items. So, to promote biofortified products we had to focus on educating rural males and urban females.

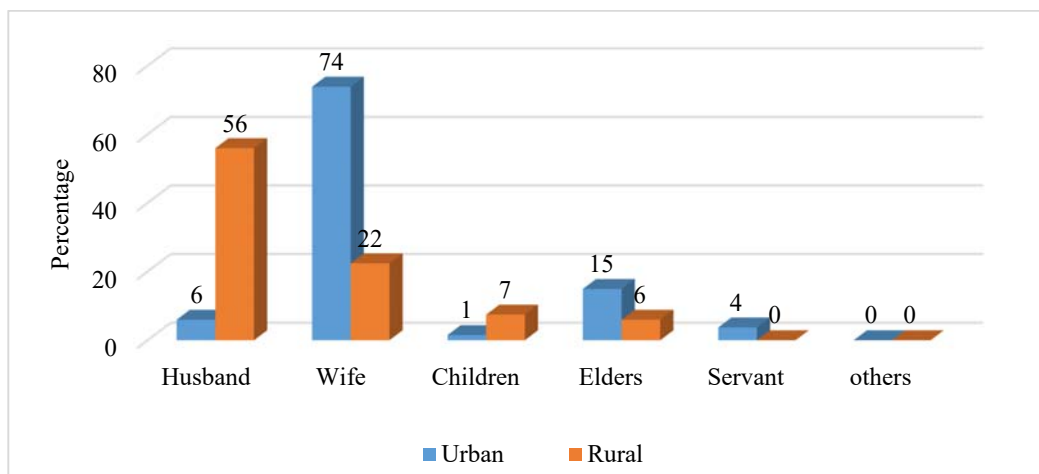


Figure 4.2 Decision maker in purchasing food items

4.3.2 Stakeholders awareness regarding biofortification

Figure 4.3 specified the sources of information along with their number of urban and rural respondents. The figure shows the percentage of respondents along with the source of information. In the urban study area, internet (39 %) was the main source of awareness and then comes the newspaper (20 %) and television (13 %). Whereas in a rural area, training (25 %) followed by relatives (17 %), exhibitions (16 %) and friends (13 %) were the main sources of information.

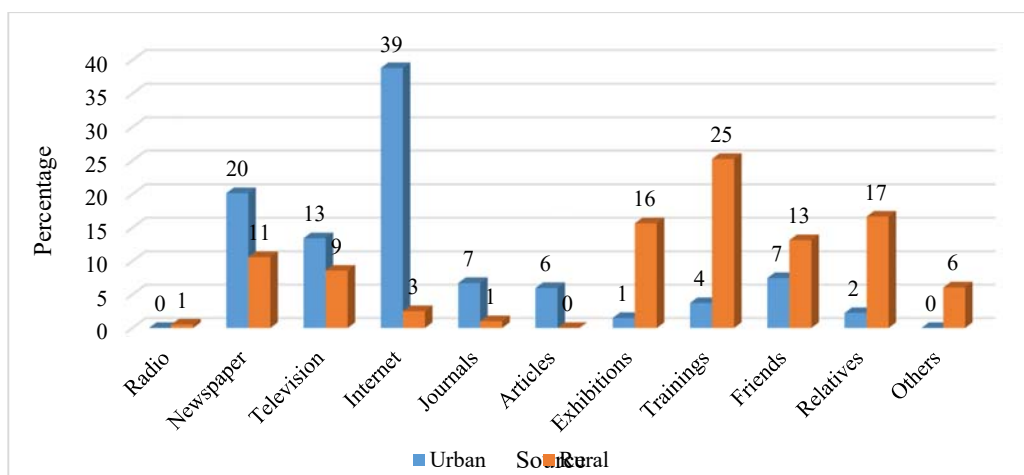


Figure 4.3 Sources of information about biofortification

Although respondents were informed, they were aware of biofortification, whether they rightly aware and their extent of awareness was studied through 6 questions. The Table 4.20 showed that in the urban area, 78.33 % of the respondents

were rightly aware that in biofortification, the nutritional quality of food crops can be improved during plant growth through any one of the given practices such as agronomic practices, modern biotechnology or genetic engineering and conventional plant breeding methods. However, 40 % of the respondents were having the misconception that in biofortification, micronutrients are added to food products physically during processing and 30 % of them perceived that biofortification means supplying nutrients through capsules, syrups, or pills.

Table 4.20 Awareness level of respondents about biofortification

SL. NO	Statements	Rightly aware (%)		
		Urban (n=60)	Rural (n=61)	Pooled (n=121)
1.	In biofortification, the nutritional quality of food crops is improved during plant growth through agronomic practices	38.33	83.61	61.16
2.	In biofortification, the nutritional quality of food crops is improved during plant growth through conventional plant breeding	61.67	81.97	71.90
3.	In biofortification, the nutritional quality of food crops is improved during plant growth through modern biotechnology or genetic engineering	81.67	63.93	72.73
4.	In biofortification, any of the above or all of the above techniques are followed for improving the nutritional value of the crops	78.33	62.30	70.25
5.	Biofortification is a commercial approach in which specific micronutrients are added to food products physically during processing	60.00	68.85	64.46
6.	In biofortification, relatively large doses of micronutrients are supplied in the form of capsules, syrups, or pills	42.00	47.00	89.00

Based on the awareness scores, knowledge index was categorized into four groups viz., not aware, slightly aware, moderately aware, completely aware. Figure 4.4 shows that majority of the respondents were moderately aware in both rural and urban

areas. About 11 % of the rural respondents and 18 % of the urban respondents were scored zero which indicates they had completely unaware about biofortification, however they believed, they were aware of the biofortification.

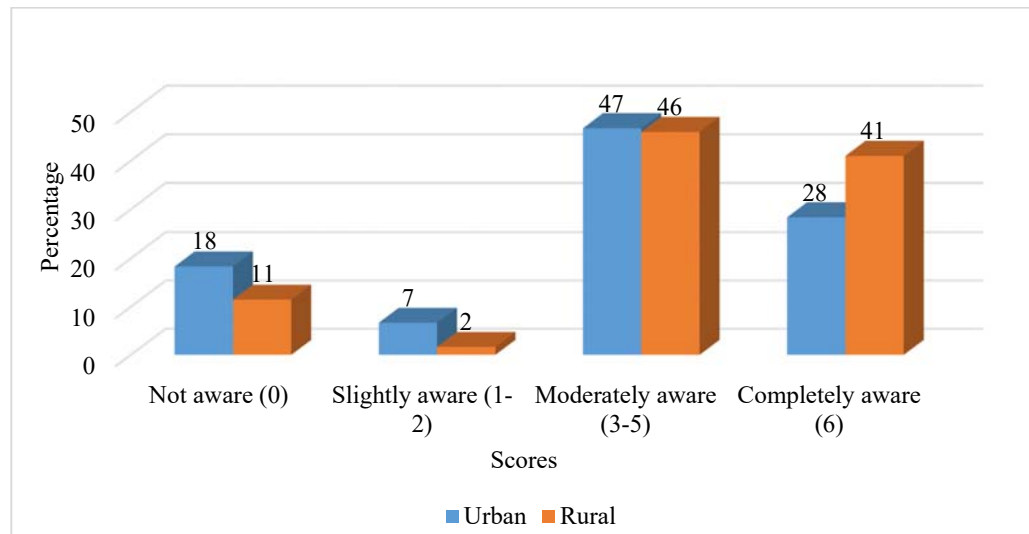


Figure 4.4 Knowledge index

For analysing determinants of consumers’ awareness on biofortification, binary logit analysis was done and the results were presented in Table 4.21. Among the regressors, age, gender, education was found to be a significant factor that influenced consumers’ awareness of biofortification, while household size, food habits, the decision maker (one who influences the food items purchase) had an insignificant effect on awareness in both urban and rural areas. Whereas in pooled data, food habit also became a significant factor which influenced awareness. The coefficient values explain the probable influence of each regressor on awareness and the marginal effects measure the actual effect of instantaneous changes in each of the explanatory variables on consumers’ awareness.

Age of consumers negatively and significantly influenced the consumers’ awareness. The result implies that younger age group was more likely to be aware of biofortification and the marginal effect results showed that the increase in age of respondent by one year reduced the probability of being aware of biofortification by 1.1per cent. The effect of gender was negative and significant. The result showed that male respondents on an average 31 % less aware than the females. In addition, education and income had an insignificant influence on the level of consumer awareness. The results indicated that an increase in 1 unit of education (number of years

of schooling) and income resulted in increasing the probability of being aware of 4.7 % and 0.8 % respectively. The pooled analysis indicates that location was not a significant factor which means there was no significant difference between urban and rural consumers in awareness level.

Table 4.21 Determinants of awareness (Binary logit estimates of determinants)

	Urban	Rural	Total
Age	-0.066* (0.038)	-0.034* (-1.68)	-0.044*** (0.017)
Gender	-0.965** (0.469)	-1.755*** (-2.92)	-1.301*** (0.349)
Household size	0.020 (0.283)	0.024 (0.28)	0.020 (0.081)
Education	0.246*** (0.098)	0.201*** (3.22)	0.189*** (0.046)
Food habit	-0.010 (0.462)	-0.113 (-0.11)	0.134*** (0.042)
Income	0.031*** (0.011)	0.139*** (3.22)	0.033*** (0.011)
Decision maker- Husband	-0.335 (1.139)	0.441 (0.79)	0.376 (0.479)
Decision maker - Children	1.007 (1.720)	0.111 (0.09)	0.352 (0.949)
Decision maker - Elders	-0.661 (0.677)	-0.720 (-0.67)	-0.584 (0.522)
Location	-	-	-0.872 (0.911)
Constant	-2.673* (2.431)	-1.978* (-1.28)	-1.693 (1.061)
Log likelihood	-61.09	-56.01	-118.65
Pseudo R2	0.308	0.3430	0.3206
χ^2 (ρ - value)	54.39 (0.000)	58.49 (0.000)	111.99 (0.000)
No. of observations	129	123	253

Note: Standard errors in parentheses; statistical significance levels: ***1%; **5%; *10%

Table 4.22 Marginal effects after logit

variable	dy/dx (Urban)	dy/dx (Rural)	dy/dx (Total)
Age	-0.015* (0.009)	-0.008* (0.005)	-0.011*** (0.004)
Gender	-0.224** (0.107)	-0.413*** (0.125)	-0.312*** (0.078)
Household size	0.005 (0.066)	0.006 (0.022)	0.005 (0.020)
Education	0.057*** (0.022)	0.050*** (0.016)	0.047*** (0.011)
Food habit	-0.002 (0.107)	-0.028 (0.258)	0.033*** (0.010)
Income	0.007*** (0.003)	0.035*** (0.011)	0.008*** (0.003)
Decision maker- Husband	-0.074 (0.239)	0.110 (0.138)	0.093 (0.119)
Decision maker - Children	0.246 (0.409)	0.028 (0.297)	0.088 (0.236)
Decision maker - Elders	-0.142 (0.132)	-0.175 (0.245)	-0.138 (0.116)
Location	-	-	-0.213 (0.215)

Note: Standard errors in parentheses; statistical significance levels: ***1%; **5%; *10%

4.3.3 Stakeholders perception regarding biofortified products

In order to study the perception of biofortified products, respondents were asked to rate using a Likert scale ranging from strongly disagree to strongly agree. Figure 4.5 shows that majority of the respondents (72 %) in urban areas opined that biofortified products were rich in micronutrients while only 49 % of the rural consumers perceived the same. Rest of them falls in the agreed category for this statement in both the areas. Similarly, 100 % of the respondents belonged to either strongly agreed or agreed on category with respect to the statement that biofortified foods can help in fighting nutrient deficiency especially in low-income populations and rural regions. As far as

taste was concerned, respondents were asked to rate the statement biofortified product is tasty. In response, 52 % of the respondents agreed and 35 % of respondents disagreed in urban areas, while 44 % of respondents agreed and 33 % of participants agreed strongly in rural areas. About 18 % of the urban respondents opined that the biofortified foods are risky for human consumption and the environment. Similarly, 8 % of the rural respondents believed that it was risky for human consumption, while 13 % of them opined that it is risky for the environment.

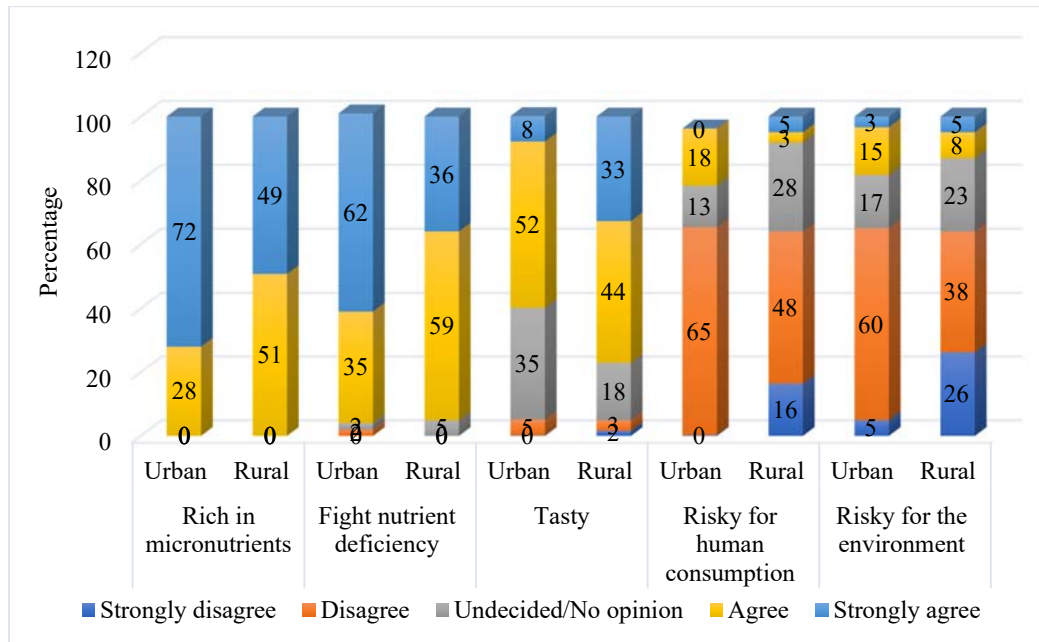


Figure 4.5 Stakeholders perception

4.3.4 Consumers' food purchasing behavior

With regard to the purchasing behavior of the newly arrived food products in the market (Fig. 4.6), 10 % of the respondents informed that they always purchase the new products in both urban and rural area. Whereas in an urban area, 24 % of the respondents reported that they purchase often the new products and in rural areas only 7 %. In both areas, there were approximately equal %ages of respondents who buy the newly arrived products sometimes (33-40 %) and rarely (28-29 %). More so, the majority of rural consumers (15 %) rated never to the newly arrived products than urban respondents (4 %). Therefore, it was consistent that urban consumers were more willing to purchase new products than the rural consumers (Table 36).

Later, respondents were asked about their behaviour in buying biofortified products and the outcome showed that 83 % of urban participants and 59 % of rural

participants were willing to buy a biofortified product if it was made accessible on the market (Table 4.36). Respondents were asked about their opinion regarding the requirement of promotion and advertisements for biofortified products and out of them, 86 % of the urban respondents and 90 % of the rural respondents said that the products need to be advertised and promoted.

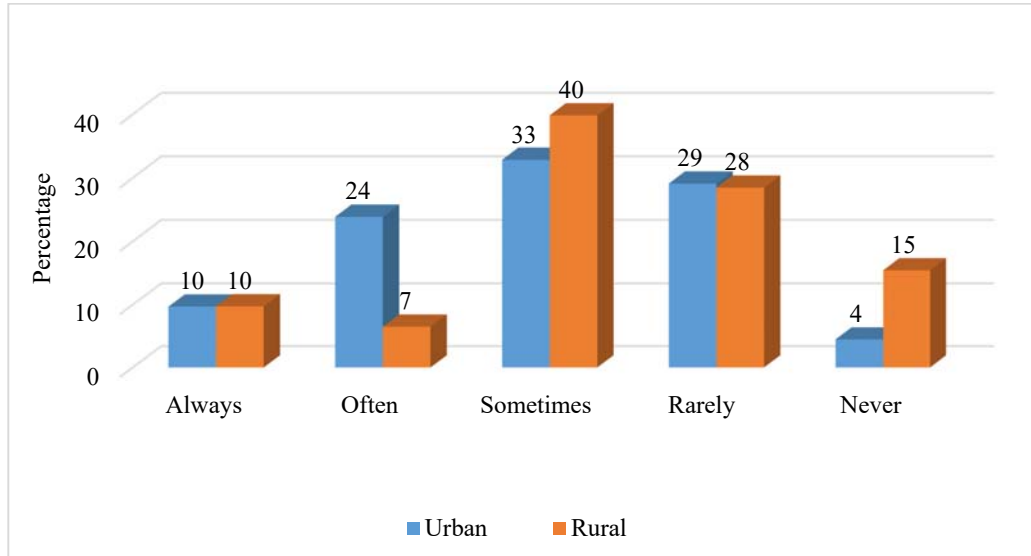


Figure 4.6 Purchasing behaviour of the respondent's regarding newly arrived food products

Table 4.23 Food purchasing behavior

1.The purchasing behaviour of the biofortified products	Urban	Rural
1. Yes	83	59
2. No	17	41
2.Opinion regarding the requirement of promotion and advertisements for biofortified products		
1. Yes	86	90
2. No	14	10

To determine the most important factors that influence food purchase, respondents were asked to rate five product characteristics viz., taste/ flavor, price, nutritional information, brand name and additional health information according to their level of importance prior to purchasing using a Likert scale ranging from not at all important to very important. As reported in Figure 4.7, 84 % of the urban and 70 % of

the rural respondents ranked taste/ flavor as very important. While, 26 % of the urban respondents ranked that price was not important and 38 % of the rural ranked that price was a very important factor. Urban respondents were more conscious regarding the nutritional information and 50 % of them ranked it as very important and in rural only 22 % of the respondents ranked as very important. More than 50 % of the respondents in both the study area ranked that brand name was very important for them while purchasing the product. For the additional health information, 28 % of the urban respondents and 16 % of the rural respondents ranked as very important.

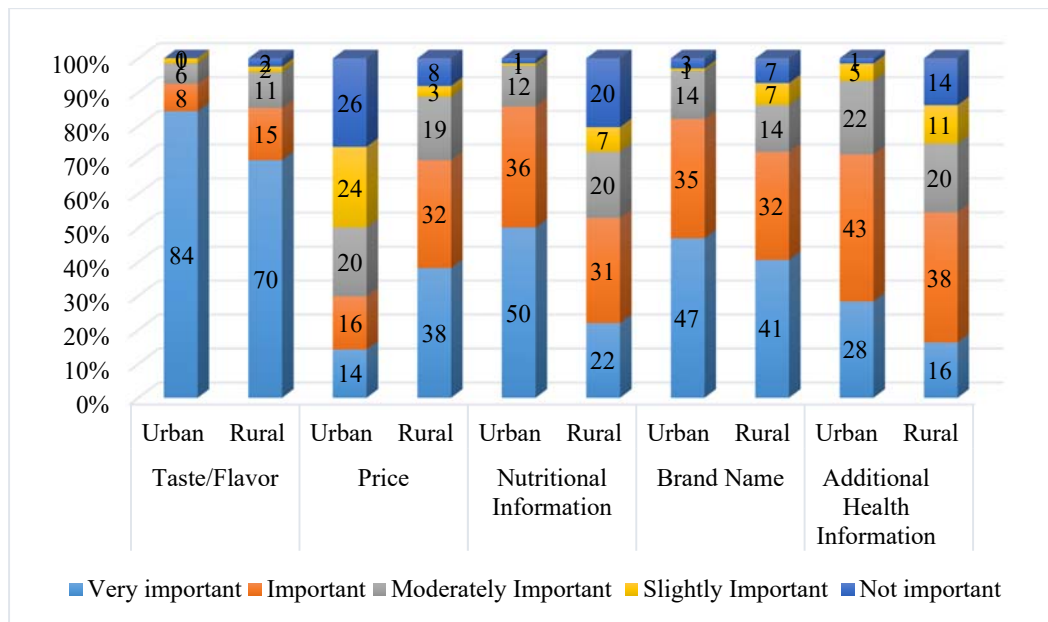


Figure 4.7 Factors influencing food purchase

4.3.4 Willingness to pay for the biofortified product

In the structured schedule, the respondents were asked whether they are willing to buy biofortified mustard oil if it made available in supermarkets and other stores. All 257 respondents were willing to purchase the biofortified mustard oil. The respondent's willingness to pay was analysed through a double bound contingent valuation method (CVM). The first step in CVM to test the randomness of the bids and price test. There were 6 randomly assigned initial bids for a litre of mustard oil which ranged from 100 to 150 The bids were calculated based on the average price of the normal mustard oil and the average price was Rs. 100. The randomness test result was presented in Table 4.24. The bid sizes were increased or decreased based on the 10 % difference of the

average price. The randomness test for initial bid shows that different initial bids have equal representation ranging from 22 to 23 frequencies per bid.

Table 4.24 Test of the randomness of initial bids

1 st bid	Urban		Rural		Total	
	Frequency	%	Frequency	%	Frequency	%
100	23	17	21	17	44	17
110	22	16	19	16	41	16
120	23	17	21	17	44	17
130	22	17	20	16	42	16
140	22	17	21	17	43	17
150	22	16	21	17	43	17
Total	134	100	123	100	257	100

The price test results are given in Table 4.25 which shows the proportion of yes or no answers to the corresponding initial and follow up bids. When the initial bid of lower price was quoted, a greater number of respondents were willing to pay and as the price of the initial bid was higher, lesser and lesser number of respondents were willing to buy at that price i.e., as the price of the oil increases, the number of no responses increases and yes responses decreases.

Table 4.25 Price test results

	Answer	100	110	120	130	140	150	Total
Urban	0	8.7	4.55	8.7	18.18	68.18	81.82	31.34
	1	91.3	95.45	91.3	81.82	31.82	18.18	68.66
	Total	23	22	23	22	22	22	134
Rural	0	33.33	21.05	42.86	40	61.9	76.19	46.34
	1	66.67	78.95	57.14	60	38.1	23.81	53.66
	Total	21	19	21	20	21	21	123
Total	0	20.45	12.2	25	28.57	65.12	79.07	38.52
	1	79.55	87.8	75	71.43	34.88	20.93	61.48
	Total	44	41	44	42	43	43	257

The data were analysed by using Doubleb command in STATA, which gives directly the value of WTP for biofortified oil. The WTP was highly significant. As reported in Table 4.26, the urban and rural respondents were willing to pay Rs. 135.87

and Rs. 126.96 which is 35.87 % and 27 % higher than the existing mustard oil price respectively. The pooled willingness to pay for the biofortified oil was Rs. 131.91 which is 31.91 % higher than the normal price of the mustard oil.

Table 4.26 Estimates of WTP with no controls

		WTP Coefficient	Std. Err.	P> z
1.	Urban	135.87	2.029	0.000
2.	Rural	126.96	2.559	0.000
3.	Pooled	131.91	1.658	0.000

Table 4.27 shows the results of WTP analysis with control variables. The variables like income, education and food habits in urban and gender, income in the rural study area were found significant. In pooled data, only income and food habits found significant.

Table 4.27 Coefficient estimates for double bound contingent valuation model

	Urban	Rural	Pooled
Age	0.103 (0.196)	0.170 (0.200)	0.137 (0.136)
Gender	3.887 (3.694)	-10.958* (6.242)	-1.893 (3.396)
Income	0.177*** (0.072)	0.802*** (0.331)	0.000*** (0.000)
Household size	0.096 (1.943)	-0.330 (0.889)	0.179 (0.695)
Food habits	15.000*** (3.662)	5.662 (8.219)	13.496*** (3.843)
Awareness	-0.542 (4.149)	0.776 (6.055)	2.160 (3.625)
Education	1.031** (0.485)	0.548 (0.582)	0.528 (0.366)
Location	-	-	6.967 (5.312)
Constant	99.934*** (13.492)	104.299*** (13.008)	98.825*** (8.532)
Log-likelihood	-120.587	-150.56263	-278.037
χ^2 (ρ - value)	36.81 (0.000)	12.97 (0.073)	43.16 (0.000)
No. of observations	134	123	257

Note: Statistical significance levels: *** 1%; ** 5%; * 10%. Corresponding standard errors are shown in parentheses

As observed in Table 4.28, urban and rural participants were willing to pay Rs 136.49 and Rs 127.25 which is 36.49 % and 27 % greater than ordinary mustard oil respectively. After adding the control variables in the model, the WTP estimates slightly increased when compared to the without any control variables.

Table 4.28 Estimates of WTP with control variables

		WTP Coefficient	Std. Err.	P> z
1.	Urban	136.49	1.773	0.000
2.	Rural	127.25	2.425	0.000
3.	Total	132.58	1.532	0.000

The individual WTP was estimated by using predict WTP command in STATA. Multiple linear regression was employed to identify determinants of predicted WTP. As WTP was predicted from the model, the regression model was highly significant and R-square value is very high that is 1. R-square indicates the variation in WTP was completely explained by the model (Table 4.29). These results show the strength of each variable contribution in determining WTP, higher and positive coefficients indicate a higher willingness to pay. In the urban area, all the variables except awareness were positive and in a rural area, all variables except gender and household size were positive. In pooled data, all variables except gender were positive and significant.

Table 4.29 Determinants of WTP

	Urban	Rural	Total	Std. Err.	P> z
Age	0.103	0.170	0.137	0.000	0.000
Gender	3.887	-10.958	-1.893	0.000	0.000
Income	0.177	0.802	0.249	0.000	0.000
Household size	0.096	-0.330	0.179	0.000	0.000
Food habits	15.000	5.662	13.496	0.000	0.000
Awareness	-0.542	0.776	2.160	0.000	0.000
Education	1.031	0.548	0.528	0.000	0.000
Location	-	-	6.967	0.000	0.000
Constant	99.934	104.299	98.825	0.000	0.000
Number of observations	134	123	257		
Prob > F	0.000	0.000	0.000		
R-squared	1.00	1.000	1.000		
Adj. R-squared	1.000	1.000	1.000		

DISCUSSION

The present study was aimed to know the status of the biofortified varieties in India and attempts to analyse the costs involved in the development of varieties and returns in terms of monetary gain due to incremental micronutrient consumption and DALY saved and its monetary value. The study will also help us to know the awareness and perception of stakeholders and its acceptance about the biofortified variety. The discussion on salient results is presented in the following sections.

5.1 Status of the biofortified varieties in India

5.2 Cost of development of selected IARI biofortified varieties and ex-ante health benefits

5.3 Stakeholders' perception about the biofortified variety and willingness to pay by consumers

5.1 Status of the biofortified varieties in India

Agricultural research has increased the production and availability of calorically dense staple crops for developing countries over the past 50 years, but the production of non-staples rich in micronutrients, such as vegetables, pulses and animal products, has not increased equally. Non-staple food prices have steadily and substantially risen, making dietary quality more and more difficult to afford for the poor (Bouis *et al.*, 2011). At present, the situation to remove hunger and malnutrition, the crops which are biofortified have potential future. In India, there are totally 21 biofortified varieties which are developed by the different institution in diverse crops areas. Maize crop leading with 4 varieties which are improved in the provitamin-A, tryptophan and lysine content followed by pearl millet (3 varieties), rice and wheat with two varieties each. A large number of varieties are improved with the Zinc content, it was higher in case of wheat followed by pearl millet and sorghum. The improvement in the iron content is much more in pearl millet followed by lentil and pomegranate varieties.

One variety in maize called Pusa Vivek QPM9 improved is having higher provitamin A content along with tryptophan and lysine. The cauliflower and potato variety showed improvement in β -carotene content up to an extent of 14 mg/100g which is the precursor of vitamin A.

The erucic acid and glucosinolates are having rich in unsaturated fatty acids causes many health effects. This content was usually rich in mustard, so to reduce these contents ICAR-IARI had released two varieties which are having a low amount of both. Out of all the biofortified varieties, cereals constitute major share, i.e 13 out of 21 varieties, followed by vegetables, oilseeds and fruits.

More than 20 million people in farm households in developing countries are now growing and consuming biofortified crops (Bouis and Saltzman, 2017). When it comes to the area under cultivation of biofortified varieties in India, biofortified bajra varieties cover around 32 % of the total area under bajra having a major area with 0.236 mha which was followed by biofortified rice with 0.1129 mha area i.e. 2.5 per cent of the area under total rice cultivation. Mustard was cultivated in 0.0418 mha which covers 7 % of the total mustard area.

5.2 Cost of development of selected IARI biofortified varieties and quantification of ex-ante health benefits

Existing micronutrient interventions such as pharmaceutical supplementation or industrial fortification have their limitations and can be complemented by a new approach of breeding food crops for higher micronutrient content in it. The studies reported that knowledge regarding the cost-effectiveness of biofortification was scarce (Stein *et al.*, 2005). Therefore, it was necessary to study the cost of development of these biofortified varieties. Biofortification breeding required the development or adaptation of cost-effective and rapidly high analytical techniques for analysis of micronutrient content since thousands of samples must be tested for their mineral or vitamin content every season (Bouis and Saltzman, 2017). In this study, the development cost of four crops, i.e. maize, lentil, mustard and cauliflower, was calculated by compiling information from the respective crop breeders to workout total cost involved in breeding biofortified varieties and the costs included while calculating comprises of laboratory costs, field costs, human capital costs, germplasm costs, R & D failure costs and institutional overhead charges.

It was found that the development costs of biofortified varieties ranged from 3 to 4.5 crores. The cost of development of cauliflower was found to be the lowest (281.27 lakh rupees) among the four crop varieties (maize, lentil, mustard and cauliflower) and the highest cost of development was seen in mustard (459.87 lakh rupees). Around 40

% (maize) to 60 % (lentil) share of the total cost of development was from human capital alone followed by field and laboratory costs. The cost of the field and laboratory costs varies from 5 % in lentil crop to 35 % in maize of the total cost of development. The overhead institutional cost was 8 to 12 % of the overall cost.

The unit cost of the consumption of micronutrients from various food crops was estimated and the unit cost of zinc was discovered to be the lowest in bajra (0.83 Rs / mg of Zn) and highest in rice (2.29 Rs/mg of Zn). Whereas, the unit cost of iron was found to be the lowest in bajra (0.57 Rs/mg of Fe) and the highest in lentil (1.18 Rs/mg of Fe). The results were in line with Rao *et al.* (2006) study, where they analysed the unit cost of nutrient intake from selected food commodities in rural India and found that unit cost of zinc in bajra and rice were found to be Rs 0.46 and Rs 0.74 respectively. The unit cost of iron in bajra was found to be Rs 0.18 and they concluded that sorghum and pearl millet provided a low-cost solution for combating malnutrition due to micronutrient deficiency. It was found to be the smallest unit cost of lysine in maize (Rs 14.86). With respect to monetary gain, monthly per capita gain in zinc biofortified rice (Rs 105.97) and iron biofortified wheat (Rs 39.5) was discovered to be the highest. It was estimated that if biofortified foods share 2 % of the total consumption of rice by the total population in the country then the monetary gain due to incremental zinc consumption was about Rs 3,077 crores/year, similarly for wheat Rs 1,077 crore/year, for bajra Rs 34.5 crores/year. Similarly, the monetary gain due to incremental iron consumption was found to be Rs 1,135 crore/year for wheat, Rs 38.31 crores/bajra and Rs 27.31 crores/year for lentil, if biofortified crops of these varieties reach 2 % of their total consumption of respective foods.

The present burden of zinc deficiency in India, i.e. the situation 'without' biofortification, can be expressed as the number of DALYs lost. Based on the present consumption pattern, zinc deficiency in India was responsible for a per capita loss of 0.102 DALYs (15.83 million DALYs). There was evidence from Meenakshi *et al.* (2010) study that 80,000 DALYs were lost due to deficiency of zinc in the Philippines, 0.44 million DALYs lost in Bangladesh and 2.84 million DALYs lost in India.

With respect to the regional differences, the number of DALYs lost was significantly higher in wheat consuming region (0.103). Due to the differences in the regional attribution level of zinc deficiency, the relative burden in rice-wheat consuming states was significantly lower with 0.1 DALYs lost. The benefits to public

health can be assessed by comparing the number of DALYs lost under the current situation ('without') and with biofortification scenario. The results of the potential health benefits of zinc biofortification were expressed as the number of DALYs saved through the consumption of zinc biofortified products. This was the difference between the number of DALYs lost under the current situation and the DALYs lost under the biofortification scenario and saves 0.339 DALYs in the biofortification scenario. The health impact in the wheat-consuming region is significantly lower. Depending on the assumptions made, the consumption of zinc biofortified products in India could save 1.59 million DALYs.

5.3 Perception of stakeholders about the biofortified variety and willingness to pay by consumers

The average age of respondents in the whole sample was 38.75 years, indicating that most of them are of middle age and respondents younger than 15 years were not selected for the interviews as it was assumed that the younger respondents had less experience in shopping and would give biased responses (De Groote *et al.*, 2010). More female respondents (51 %) answered in a rural area than males (49 %) because individuals in the study areas were selected based on availability and responsibility for food purchase in the household. Whereas in urban, it was found that male respondents were more in number (55 %). On average, the household size among respondents was five members with a range of 2 to 17 members in the house. The tabular analysis shows that majority of rural respondents (53 %) stated that agriculture was their main livelihood activity and in urban it was stated wage/salaried employment (66 %). The results also showed that the average income in an urban and rural area was Rs 52300 and Rs 16,300. On average, respondents had 11.65 years of formal education, with most of them having secondary education (32.43 %). There were also some respondents with no formal education at all (11.35 %).

The study examined the respondent's awareness of biofortification to address the knowledge level of biofortification. Group statistics showed that 49.59 % of the rural respondents and 44.73 % of the urban respondents are aware of biofortification and it showed that rural respondents are generally more aware than urban respondents. The institutional training, health programmes, ongoing programme on nutrition and where they were made the prime targets might have created or reinforced the high

awareness rate of biofortification as in the case of the rural study area. This was because of these households (De Groote *et al.*, 2010).

The source of information also influences biofortification awareness. The results indicate that 39 % of the urban respondents were aware of biofortification mainly through internet source, whereas in the rural study area, the respondents were mainly aware because of training (25 %).

Although the explained variance of our logit model was rather low, it does appear to be useful to explore the sign and impact of some of the important determinants of awareness. As expected, awareness was determined by age, gender, household size, education, food habit, income, decision maker and location factors. Linking these findings with respondent's awareness made it possible to formulate recommendations which deserve specific attention. Five socio-demographic indicators, i.e. age, gender, education, food habit and income played a significant role in determining awareness. On the other hand, age of respondents negatively and significantly influences awareness of biofortification since they were more exposed to numerous modern technology-based channels of information dissemination including mobile phones, Facebook and other internet-based information channels (Okello *et al.*, 2009). The marginal effect results show that an increase in the age of the respondent by one year reduces the probability of being aware of 1%. Moreover, the information has gone digital due to technological advancement so that even food advertisers seek new avenues so as to keep track of the changing times (Okello *et al.*, 2015). Internet options and mobile phone usage have provided the medium for new advertisement opportunities that target mostly technologically advanced respondents. The younger respondents get favour in these new avenues which may explain their high level of awareness. Female may also be more aware of biofortification due to their responsibility for food purchase and preparation.

The average price consumers stated that they WTP for 1 litre of biofortified mustard oil was Rs. 132.58 which was significantly higher than the average price of 1 litre of conventional mustard oil (Rs 100) i.e. mean willingness to pay for biofortified mustard oil increased by 32.58 %. Similar to our results, positive results obtained in Maharashtra, the mean WTP for biofortified high-iron pearl millet (HIPM) increased by 12 % (Banerji *et al.*, 2016).

Based on the estimation of both urban and rural consumers, respondents in the urban study area were willing to pay significantly more (9.34 %) for biofortified mustard oil than those in a rural area. The linear regression analysis reveals that female respondents, respondents with a high income or education level, large household size, vegetarian and those who were aware of biofortification, and urban consumers stated a higher WTP value whereas younger respondents stated a lower WTP value.

SUMMARY AND CONCLUSION

Micronutrient deficiencies continue to haunt the developing world since micronutrient malnutrition have a debilitating effect on health which leads to the onset of several diseases and disabilities causing distress and also an economic loss to an individual, household and the country (WHO, 2006). The resulting human suffering and the economic losses could be totally avoided by the right strategies of addressing the menace. One of the main strategies to combat micronutrient deficiency is through biofortification which was regarded as the most effective and least expensive method of eliminating micronutrient deficiencies.

In this regard, the study entitled, “Impact Assessment of Biofortified varieties of IARI” was an attempt made for understanding the status of the biofortified varieties in India, cost of varietal development and consumers awareness and acceptance level. This study has been undertaken with three specific objectives:

1. To study the status of the biofortified varieties in India
2. To analyze the cost of development of selected IARI biofortified varieties and quantification of ex-ante health benefits
3. To examine the perception of stakeholders about the biofortified variety and willingness to pay by consumers

To accomplish these objectives, both primary and secondary data were used. Secondary data on bio-fortified crops such as varieties released and its characteristics, its seed indent, nutrient content and productivity were obtained from various sources like ICAR-IARI, Seed net portal, Harvest Plus and to work out the ex-ante health benefits of biofortified varieties and monetary gain from biofortification, secondary data from NSSO, the Population Census 2010-11, DES, WHO and MOSPI was utilized. To calculate the cost of development of varieties, primary data on cost structure was collected from respective crop breeders. To study the awareness, perception, and willingness to pay for the biofortified product, survey data were collected from 134 urban respondents of NCT region and 123 rural respondents from three villages Basi, Sunehra and Lahchauda of Bhagpath district in Uttar Pradesh.

The tabular analysis was done for calculating the area covered under biofortified varieties using breeder seed indent and incremental micronutrient content in biofortified varieties. Per-capita per day monetary gain and DALY method was used to quantify the ex-ante health benefits. Knowledge index, binary logit model and marginal effects were estimated to know the extent and determinants of awareness. Since the data on perception and factors influencing food purchase was qualitative, we had chosen Likert-scale, which analysed the responses of respondents. Double bounded contingent valuation method (CVM) was used to calculate the consumers' willingness to pay for biofortified mustard oil and regression analysis to estimate determinants of WTP were used in this study.

By compiling all the biofortified varieties, it was found that Zn content was enriched in rice, wheat, pearl millet and sorghum, iron content in wheat, pearl millet, lentil and sorghum, β -carotene in cauliflower and potato, Tryptophan, Lysine and Provitamin-A content in maize, anthocyanin and vitamin c content in sweet potato and pomegranate. In all the biofortified varieties, micronutrient content was higher except in mustard, where erucic acid and glucosinolate content were found less. The difference in micronutrient content in biofortified varieties was significantly higher than the normal varieties. Among the biofortified varieties like rice, wheat, mustard and lentil, the estimated area and its share in the total area covered under that crop were found very meager i.e. less than 10 % in the total area except for bajra which accounts for 32.32 % in the total area covered under bajra.

The cost of biofortification involves adaptive breeding, research and development, maintenance and dissemination. The R & D costs used for the cost-effectiveness study was calculated for four varieties of ICAR-IARI namely maize, lentil, mustard and cauliflower. The cost of development of all varieties ranged from 3 to 4.5 crores and it was found that the share of human capital accounted for a major cost ranging from 40 to 70 % of the total cost. Field level cost ranged from 5 to 25 % and institutional overhead cost ranged from 8 to 12 % of the total cost of development of the variety.

The unit cost of micronutrients intake from different food crops had been estimated and the unit cost of zinc and iron was found to be lowest in bajra (0.83 Rs/mg of Zn and 0.57 Rs/mg Fe) and highest in zinc and iron in rice (2.29 Rs/mg of Zn)

and lentil (1.18 Rs/mg Fe) respectively. In maize, the unit cost of lysine was found to be lowest (Rs 14.86). In terms of monetary gain, monthly per capita gain was highest in zinc biofortified rice (Rs 105.97) and in iron biofortified wheat (Rs 39.5).

DALY method was used to compare the ex-ante health benefits in both pessimistic and in optimistic ways. In the optimistic scenario, the results of DALYs lost due to zinc deficiency in India lowest in rice-wheat-millet consuming region (0.065) with all India average per capita DALY lost was found to be 0.068. The monetary gain was found to be highest in the rice-wheat-millet region (0.0374) and with all India average monetary gain of Rs 2,933.94 and the total disease burden saved by zinc biofortification in India accounts for Rs. 455 bn.

This study also aimed to explore consumers awareness and perception regarding biofortification. Knowledge scores highlighted that the awareness on biofortification was slightly higher in rural consumers than urban and the awareness scores indicate that 25 and 17 % of rural and urban respondents were coming under highly aware category. However, it was to be noted that the rural sample was mainly taken from the IARI adopted villages, therefore it cannot be generalized. The source of information regarding biofortified varieties in urban was mainly through the internet (39%) and in the case of rural, it was through training (25%). The results from binary logit regression showed that gender, education, food habits and income were the significant factors influencing consumers' awareness of biofortification. Age and gender (base: male) negatively affected awareness while education, food habit and income affected awareness positively.

This study provided the results of consumer willingness to pay for biofortified mustard oil against conventional mustard oil. CVM was used to calculate the WTP in both urban and in a rural region and the analysis revealed that consumers were WTP pay a premium for biofortified mustard oil. It was found that urban and rural consumers WTP were 36 and 26 % more than the existing price, and results showed that urban consumers were willing to pay more than that of the rural consumers. Further, determinants of WTP were analyzed, regression analysis showed that age, gender, income, household size, food habits, awareness, education and location were found factors which determine willingness to pay for biofortified products. The policy implications drawn from the study are as follows

Policy implications

- Based on the breeder seed indent the extent of area adoption was estimated and it showed a very low level of adoption in the majority of the crop varieties except for bajra. Therefore, efforts should be made to make available the quality seeds of biofortified varieties to all the farmers.
- Apart from the expected cost-effectiveness, preliminary cost–benefit analyses in terms of R & D and monetary gain show that investments into biofortification are highly favorable in combating malnutrition. Therefore, the government should fund more biofortification varietal developmental programmes.
- The findings from the study provide insights regarding stakeholder’s knowledge and awareness regarding biofortification which has the potential to influence policy development and can serve to guide strategies for promoting micronutrient-rich products. Arranging training programs by government institutions and other non-profit organizations can be used to supplement media sources in rural areas, in disseminating information. In addition, mobile phones, the internet should be considered, since there is evidence of its wider use in literature among urban consumers.
- Further research is required to understand the link between consumers’ awareness and their perception of biofortified foods. This would enable the designing of consumer-based food products and could increase the acceptance rates of consumers.
- The growing market for enriched foods, especially biofortified products, provides a potential opportunity to improve the health and enable the development of new micronutrient-rich food products. This study showed that consumers were willing to pay a premium price for the biofortified product, by developing a niche market and by appropriate marketing channel, the farmers also can get better prices for their products.

Impact Assessment of Biofortified varieties of IARI

ABSTRACT

Micronutrient-related malnutrition, which includes vitamin and mineral deficiencies in human diets is an all-pervasive nutritional problem in developing countries. Malnutrition increases the cost of health care, lowers productivity, and slows economic growth, which can sustain a cycle of poverty and ill health and more likely to affect people who are poor. To address micronutrient malnutrition, four main strategies were commonly used, namely dietary diversification, fortification, supplementation, and biofortification. The literature suggests that the health status of deficient individuals could be improved by increased intake of micronutrients through biofortified crops and was also one of the initiatives to achieve improved nutrition among the poor and was likely to be a cost-effective public health intervention in comparison with commercial fortification and supplementation. In the case of developing countries, approaches to food supplements and commercially marketed fortified foods is limited and in order to ensure better nutritional outcomes, there was a need for in-depth study of biofortified varieties in India and this study would help us to know the status, awareness and perception of stakeholders and its acceptance about the biofortified varieties. Both primary and secondary data were used. Data on bio-fortified crops such as varieties released and its characteristics, its area, production and productivity were obtained from various sources like ICAR-IARI, Seed net portal, AICRP reports and Harvest Plus. The cost of human capital, field costs, costs of lab testing, germplasm and cost of failures were considered for estimating the cost of development of varieties. In order to work out the ex-ante health benefits of biofortified varieties and monetary gain from biofortification, secondary data from NSSO, Census 2010-11, Directorate of Economics and Statistics (DES), The World Health Organization (WHO) and the Ministry of Statistics and Programme Implementation (MOSPI) were compiled. A primary survey was conducted among the rural and urban consumers in and around NCT region about the biofortified crops' awareness, perception and premium price for the biofortified product. In total 134 and 123 respondents from the urban and rural area were interviewed, respectively. It was found that incremental micronutrient content in biofortified varieties was significantly higher than the normal varieties. The area covered by biofortified varieties in the total area of respective crops was less than 10 percent in most of the crops. The cost of development of biofortified varieties was in

the range of 3 to 4.5 crores per variety and the human capital share was the highest (40 to 60 %). The unit cost of micronutrients intake from different food crops have been estimated in which the unit cost of zinc and iron was found to be lowest in bajra (0.83 Rs/mg of Zn and 0.57 Rs/mg Fe) and highest in zinc and iron in rice (2.29 Rs/mg of Zn) and lentil (1.18 Rs/mg Fe) respectively. The incremental zinc and iron consumption in terms of monetary value from the monthly consumption were highest in rice (Rs 105.97) and wheat (Rs 39.5). Results from binary logit regression showed that gender, education, food habits and income were the significant factors influencing consumers awareness of biofortification. Double bound Contingent Valuation Method (CVM) was used to calculate the consumers WTP for biofortified mustard oil and it was found that urban and rural consumers WTP was 36 and 26 % more than the existing price and results showed that urban consumers were willing to pay more than that of the rural consumers.

Keywords: Malnutrition, Biofortification, DALY((Disability Adjusted Life Years), WTP(Willingness to Pay), CVM(Contigent Valuation Method)

भारतीय कृषि अनुसंधान संस्थान की बायोफोर्टिफाइड किस्मों के प्रभाव का आकलन

सार

विकासशील देशों में सूक्ष्म-पोषक तत्वों से संबंधित कुपोषण, जिसमें मानव आहार में विटामिन और खनिज की कमी शामिल है, एक सर्व-व्यापक पोषण संबंधी समस्या है। कुपोषण से स्वास्थ्य देखभाल की लागत बढ़ जाती है, उत्पादकता कम हो जाता है, और आर्थिक विकास धीमा हो जाता है। कुपोषण गरीबी एवं बीमार स्वास्थ्य के कुचक्र को बनाए रख सकता है और इससे गरीब लोगों के प्रभावित होने की अधिक संभावना रहती है। सूक्ष्म-पोषक तत्वों से संबंधित कुपोषण को हल करने के लिए चार मुख्य रणनीतियों, जैसे कि आहार का विविधीकरण, फोर्टिफिकेशन, अनुपूरण एवं बायोफोर्टिफिकेशन, का आमतौर पर उपयोग किया जाता है। साहित्य बताता है कि बायोफोर्टिफाइड फसलों के माध्यम से सूक्ष्म पोषक तत्वों की कमी वाले व्यक्तियों के स्वास्थ्य में सुधार किया जा सकता है एवं यह गरीबों के लिए अच्छा पोषण प्राप्त करने की बेहतर रास्ता हो सकता है। व्यावसायिक फोर्टिफिकेशन एवं अनुपूरण की तुलना में सार्वजनिक स्वास्थ्य के क्षेत्र में इस हस्तक्षेप की लागत प्रभावी रूप से कम होने की संभावना है। विकासशील देशों के मामले में, अनुपूरित और व्यावसायिक रूप से फोर्टिफाइड खाद्य पदार्थों का फैलाव सीमित है तथा बेहतर पोषण परिणामों को सुनिश्चित करने के लिए, भारत में बायोफोर्टिफाइड किस्मों का गहन अध्ययन करने की आवश्यकता है। यह अध्ययन हमें हितधारकों की स्थिति, जागरूकता, धारणा और बायोफोर्टिफाइड किस्मों की स्वीकृति जानने में मदद भी करेगा। इसके लिए प्राथमिक और द्वितीयक आंकड़ों का उपयोग किया गया। जारी की गई बायोफोर्टिफाइड फसलों की किस्मों की विशेषताओं, इनके क्षेत्रफल, उत्पादन और उत्पादकता पर आंकड़े आईसीएआर-आईएआरआई, बीज नेट पोर्टल, एआईसीआरपी रिपोर्ट एवं हार्वेस्ट-प्लस जैसे विभिन्न स्रोतों से प्राप्त किए गए। किस्मों के विकास की लागत का आकलन करने के लिए मानव पूंजी, भू-क्षेत्रफल, प्रयोगशाला परीक्षण, जर्मप्लाज्म और विफलताओं की लागतों की

गणना की गयी । बायोफोर्टिफाइड किस्मों के स्वास्थ्य एवं मौद्रिक लाभ की गणना के लिए एनएसएसओ, जनगणना-2011, आर्थिकी एवं सांख्यिकी निदेशालय, विश्व स्वास्थ्य संगठन और सांख्यिकी एवं कार्यक्रम कार्यान्वयन से द्वितीयक आंकड़ों को संकलित किया गया। बायोफोर्टिफाइड किस्मों के प्रति जागरूकता, धारणा और प्रीमियम मूल्य के बारे में राष्ट्रीय राजधानी क्षेत्र के पास के ग्रामीण और शहरी उपभोक्ताओं के बीच एक प्राथमिक सर्वेक्षण भी किया गया । शहरी और ग्रामीण क्षेत्र से कुल 134 और 123 उत्तरदाताओं का साक्षात्कार लिया गया ।

यह पाया गया कि बायोफोर्टिफाइड किस्मों में सूक्ष्म पोषक तत्व सामान्य किस्मों की तुलना में काफी अधिक थे । संबंधित फसलों के कुल क्षेत्रफल में बायोफोर्टिफाइड किस्मों का क्षेत्रफल अधिकांश फसलों में 10 प्रतिशत से कम था। बायोफोर्टिफाइड किस्मों के विकास की लागत प्रति किस्म 3 से 4.5 करोड़ रुपये पाई गयी और मानव पूंजी का हिस्सा उच्चतम (40 से 60%) था। विभिन्न खाद्य फसलों से सूक्ष्म पोषक तत्वों के सेवन की प्रति इकाई की लागत का अनुमान लगाया गया है, जिसमें जिंक एवं लोहे की इकाई लागत बाजरे में सबसे कम पाई गई (जिंक की 0.83 रुपये प्रति मिलीग्राम और आयरन की 0.57 रुपये/मिलीग्राम) और चावल (जिंक 2.29 रु/मिलीग्राम) और दाल (आयरन 1.18 रु/मि.ग्रा) में उच्चतम पायी गयी । बढ़े हुए जिंक और आयरन की खपत के मासिक उपभोग का मौद्रिक मूल्य चावल (105.97 रुपये) और गेहूं (39.5 रुपये) में सबसे अधिक था । बाइनरी लॉगिट रिग्रेशन के परिणामों से पता चला कि लिंग, शिक्षा, भोजन की आदतें और आय उपभोक्ताओं के बायोफोर्टिफिकेशन की जागरूकता को प्रभावित करने वाले महत्वपूर्ण कारक थे। बायोफोर्टिफाइड सरसों के तेल के लिए उपभोक्ताओं की अधिक भुगतान करने की इच्छा की गणना के लिए डबल-बाउंड-कोन्ट्रिजेंट मूल्यांकन पद्धति (सीवीएम) का उपयोग किया गया और पाया गया कि शहरी और ग्रामीण उपभोक्ता मौजूदा कीमत से 36 और 26 प्रतिशत अधिक भुगतान करने की इच्छा रखते हैं । परिणाम यह भी बताते हैं कि ग्रामीण उपभोक्ताओं की तुलना में शहरी उपभोक्ता अधिक भुगतान करने के लिए तैयार हैं ।

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ANNEXURE

ANNEXURE.1 Laboratory expenses incurred in quality testing of maize

	Years	Quantity	Price (Rs)	Total (Lakh rupees)
SRF				
(a) Molecular work	5	1	36,400/month	21.84
(b) Nutritional work	5	1	36,400/month	21.84
Backcrosses				
	Samples	Markers /sample	Cost of PCR for 1 marker	
(a) BC1F1	200	120	40	9.60
(b) BC2F1	200	60	40	4.80
(c) BC2F2	200	30	40	2.40
Equipment's				
(a) PCR		2	2,50,000	5.00
(b) GEL Electrophoresis		4	1,25,000	5.00
(c) Gel doc		1	7,00,000	7.00
Travel cost		4	65,000	2.60
Contingency		7	1,00,000	7.00
Quality analysis		50 samples	2,000	1.00
Overhead charges (15%)				10.66
Grand total				98.74

ANNEXURE.2 Human capital required for maize breeding

Human capital	Number of manpower	Salary (Lakh Rs/month)	Number of years	Total (Lakh rupees)
Scientist (60% of salary)				
(a) Senior Scientist	2	0.80	5	28.85
(b) Scientist	1	0.75	5	27.04
Technical Assistant (60% of salary)	1	0.35	5	12.6
Supporting staff (60% of salary)	1	0.30	5	10.8
Skilled Labour	1	0.40	5	14.4
Total				93.69

ANNEXURE.3 Cost of cultivation for maize

Cost of Cultivation (Rs/Hectare)	Rs/ ha
Operational Cost	
(a) Human and machine labour	19,500
(b) Input cost	5,760
(c) Interest on Working Capital	480
(d) Irrigation charges	1960
(e) Miscellaneous	200
Fixed Costs	
(a) Rental Value of Land	9,100
(b) Depreciation on Implements & Farm Building	600
(c) Interest on Fixed Capital	1900
Total	39,500
Cultivation practices of 264 rows of 3 meter 15 plants in a row (792 m ²) (with 50 % additional cost)	4,692.6

ANNEXURE.4 Cost of cultivation for lentil

Cost of Cultivation (Rs/Hectare)	Rs/ ha
Operational Cost	
(a) Human and machine labour	10,750
(b) Input cost	6,850
(c) Interest on Working Capital	500
(d) Irrigation charges	1,800
(e) Miscellaneous	450
Fixed Costs	
(a) Rental Value of Land	8,600
(b) Depreciation on Implements & Farm Building	600
(c) Interest on Fixed Capital	2,200
Total	31,750
Cost of cultivation of 1 acre for 8 years (with 50 % additional cost)	1,52,400

ANNEXURE.5 Human capital required for lentil breeding

	Number of manpower	Salary (Lakh Rs/month)	Number of years	Total (Lakh Rs)
Scientist (60% of salary)				
(a) Principal scientist	1	1.81	8	104.26
(b) Scientist	2	0.75	8	43.20
Technical Assistant (60% of salary)	1	0.35	8	20.16
Supporting staff (60% of salary)	1	0.20	8	11.52
Skilled labour	2	0.30	8	17.28
Total				196.42

ANNEXURE.6 Field and laboratory expenses incurred in mustard breeding

Expenses	Quantity	Price (Rs)	Years	Total (Lakh Rs)
Field expenses - Growing under nets for 1 hectare				
(a) Costs of net		2,50,000	8	20
(b) Iron Poles		8,00,000	2	16
Laboratory expenses				
(a) Gas liquid chromatography	1 sample -	5,000	150	8
(b) Sophisticated room	150 INR			
(c) Chemicals, Hardware, software's, etc				
Total				96

ANNEXURE.7 Human capital required for mustard breeding

Human capital	Number of manpower	Salary (Lakh Rs/month)	Number of years	Total (Lack Rs)
Scientist (60% of salary)				
(a) Principal scientist	1	1.81	8	104.37
(b) Scientist	1	0.75	8	43.26
Technical Assistant (60% of salary)	1	0.35	8	20.16
Supporting staff (60% of salary)	1	0.20	8	11.52
labour requirement	2	0.25	8	24.00
Total				203.31

ANNEXURE.8 Cost of cultivation for mustard

Cost of Cultivation (Rs. /Hectare)	Rs/ ha
Operational Cost	
(a) Human and machine labour	17,000
(b) Input cost	3,500
(c) Interest on Working Capital	3,500
(d) Irrigation charges	650
(e) Miscellaneous	1,600
Fixed Costs	
(a) Rental Value of Land	18,200
(b) Depreciation on Implements & Farm Building	550
(c) Interest on Fixed Capital	5,500
Total	50,500
Cost of cultivation of 1 ha for 8 years (with 50 % additional cost)	6,06,000

ANNEXURE.9 Human capital required for mustard breeding

Human capital	Number	Salary (Lakh Rs/month)	Number of years	Total (Lakh Rs)
Scientist				
(a) Principal scientist	1	1.81	6	78.28
(b) Scientist	1	0.75	6	32.44
Technical assistant	1	0.35	6	15.12
SRF				
(a) Molecular work	1	0.33	6	14.04
(b) Nutritional work	1	0.33	6	14.04
Daily paid labour	2	0.15	6	10.80
Temporary field labour (3 Members for 3 months in a year)	3	0.15	1.5	2.70
Total				167.42

ANNEXURE.10 Cost of cultivation for cauliflower

Cost of cultivation	Rs/Ha
(a) Field preparation	6,000
(b) Nursery and planting/sowing	10,000
(c) Weeding	10,000
(d) Plant protection	12,000
(e) Fertilizers	8,500
(f) Wages	5,000
Total	51,500
Cost of cultivation of 1 acre for 6 years (with 50 % additional cost)	1,85,400

APPENDIX

Appendix 1: Household survey questionnaire



DIVISION OF AGRICULTURAL ECONOMICS
ICAR-INDIAN AGRICULTURAL RESEARCH INSTITUTE
NEW DELHI- 110012



I. Demographic details

Name of the respondent	
Mobile/Cell phone No.	
Age (In Years)	
Gender (Male-1, Female-0)	
Number of years of education	
Occupation (Code A)	
Monthly Income (INR)	
Household size	
Location (Urban-1, Rural-0)	
Food habits (Vegetarian-1, Non-Vegetarian-0)	
The decision maker in purchasing food items (Code B)	

Code A: Agriculture-01, Agricultural labour -02, wage/salaried employment -03, non-agricultural enterprises -04, pension -05, others -06

Code B: Husband -01, Wife -02, Children -03, Elders -04, Servant -05, others -06

II. Stakeholders awareness regarding biofortification

Are you aware of biofortified products? Yes / No

If Yes,

III. Sources of information (Tick as many as)

Radio/ Newspaper/ Television/ Internet/ Journals/ Articles/ Exhibitions/ Trainings/
Friends/ Relatives/ Others Specify

	Statements	Y/ N
1.	In biofortification, the nutritional quality of food crops is improved during plant growth through agronomic practices	
2.	In biofortification, the nutritional quality of food crops is improved during plant growth through conventional plant breeding	
3.	In biofortification, the nutritional quality of food crops is improved during plant growth through modern biotechnology or genetic engineering	
4.	In biofortification, any of the above or all of the above techniques are followed for improving the nutritional value of the crops	
5.	Biofortification is a commercial approach in which specific micronutrients are added to food products physically during processing	
6.	In biofortification, relatively large doses of micronutrients are supplied in the form of capsules, syrups, or pills	

IV. Stakeholders perception regarding biofortified products

	Statements	SDA	DA	N	A	SA
1.	Biofortified products are rich in micronutrients					
2.	Biofortified products help to fight nutrient deficiency especially in low-income population and rural areas					
3.	Biofortified products are tasty					
4.	Biofortified products are risky for human consumption					
5.	Biofortified products are risky for the environment					

* SDA - Strongly disagree; DA - Disagree; N - Undecided/No opinion; A - Agree; SA - Strongly agree

V. Consumers' food purchasing behavior

	Statements	
1.	What is your purchasing behavior regarding newly arrived food products in the market? You buy_____ (Always/ Often/ Sometimes/ Rarely/ Never)	
2.	Would you buy a biofortified product if it were available in the supermarket? (Yes/No)	
3.	Do you think that biofortified products require promotion and advertisements for wider adoption? (Yes/No)	

	Factors influencing purchase	VI	I	MI	SI	NI
1.	Taste/Flavor					
2.	Price					
3.	Nutritional Information					
4.	Brand Name					
5.	Additional Health Information					

*VI - Very important; I - Important; MI - moderately Important; SI - Slightly Important; NI - Not important

VI. Willingness to pay for the biofortified product

If, in the supermarkets and other stores, the biofortified mustard oils are made available, are you willing to pay a premium price of (Select first bid) Yes/No (90, 100, 110, 120, 130, 140, 150, 160)

Value of I st bid	Yes/No	Value of II nd bid	Yes/No

How much are you willing to pay?