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SHORT COMMUNICATION

Biofortification Priority Index: Identifying Key Indian States for Combating Vitamin A and Zinc Deficiency with Biofortified Maize, Cauliflower, and Banana

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ABSTRACT

Addressing Vitamin- A and Zinc deficiency in India is very important. Biofortification is one of the most accessible methods to combat the increasing micronutrient deficiency in the country. Promotion of biofortified verities and to reach target populations we need systematic planning. In this short communication, we have utilized the modified biofortification priority indices (BPIs) to find out priority states for making effective interventions of Vitamin A enriched maize, cauliflower, and banana as well as for Zinc enriched Maize. The findings of this study are expected to help extension agencies and other development agencies to plan nutrition sensitive extension activities.

Key words: *Biofortification; Index; Vitamin A deficiency; Zn deficiency.*

In this fast-evolving modern life, our lifestyle and dietary habits are undergoing a drastic change. The portion of carbohydrates on our plates is increasing, protein and fats are also somewhat present, but presence of micronutrient- rich food is decreasing. For sustenance of human life, a complete diet that consists of both macronutrient and micronutrient, is essential. Vitamins and minerals constitute the micronutrients in a balanced diet. Vitamins and minerals have long been identified as integral components of mechanisms for healthy functioning of human body. Since the human body is unable to synthesize Vitamin A, it must be obtained through diet (Kundu et al., 2021). Apart from playing a major role in vision, vitamin A also strengthens the immune system, which protects us against many infectious diseases. Vitamin A deficiency can lead to Xeropthalmia, which can lead to severe visual impairment and Night Blindness. According to UNICEF a child's chance of survival can be increased with adequate intake of Vitamin A by 12–24 %. Zinc is another micronutrient important to the human growth pertaining to its essentiality during growth spurt in adolescents (Kawade, 2012). Even though zinc deficiency is only to blame for 0.2% of the disability-adjusted life-years lost in India last year (due to its involvement in exacerbating malaria, lower respiratory infections, and diarrheal illness), the increasing trend in its deficiency is concerning (Smith et al., 2019). According to the Comprehensive National Nutrition Survey Vitamin A Deficiency in India is 17.54% among 12–59 months children and nearly one-fifth (19%) suffered Zinc deficiency (MoHFW, 2019). Several approaches, including Vitamin supplementation, food fortification, nutrigardens, and biofortification, have been proposed to address this insufficiency (Tengli et al., 2021). Most of the tactics have been put into practice in India, apart from biofortification, which is gradually gaining popularity.

Biofortification is the process by which the nutrient density of food crops is increased through conventional plant breeding, and/or improved agronomic practices and/or modern biotechnology without sacrificing any characteristic that is preferred by consumers or most importantly to farmers (Talsma and Pachón, 2017). Biofortification is a cost-effective approach towards combating micronutrient deficiencies and it can reach even remote areas where resource poor farmers can cultivate and consume biofortified varieties of crops.

ICAR has previously launched several biofortified crops in India, including protein-rich rice (CR Dhan

310), zinc and iron-rich wheat (WB 02), pearl millet (HHB 299), iron-rich lentil (Pusa Ageti Masoor), and many more. To further cement the development towards a nutritionally secure country Vitamin A biofortified crops have also been developed and released. ICAR has released the Vitamin A biofortified cultivars Bhu Sona for Sweet Potato, Pusa Vivek QPM9 Improved for Maize, and Pusa Beta Kesari 1 for Cauliflower in the 2010s (Yadava et al., 2017). While they are still undergoing testing in India, Vitamin A rich Bananas (Bira variety) have been introduced in Burundi (India Science, 2021). India is the world's top and second-largest producer of Cauliflower and Bananas, respectively (Numerical, 2021). It is important to prioritize states in India for targeted biofortification interventions.

For prioritizing states that can have more effective outcomes when provided targeted interventions. Biofortification priority index (BPI) developed by HarvestPlus was used to identify priority states. BPI has been developed as a composite index which specially focusses on crop and micronutrients deficiency and is an advocacy tool which can help us determine regions where biofortification-related interventions can be more effective. There are three assumptions that must be followed: (1) The state must produce the crop and retain it, i.e. all the produce must be consumed; (2) Population of the state must consume a significant portion from their domestic produce, not from imports; and (3) There must be a significant prevalence of the micronutrient deficiency in the state, which the biofortified crop is focussed on addressing. Each of the above assumptions leads to formulation of a three subindex for the overall BPI calculation. A geometric mean is used for aggregation of the three sub-indices- the production subindex (PSI), the consumption subindex (CSI) and the micronutrient deficiency subindex (MDSI).

The sub-index and BPI value were computed using formulas given in the table 1, the BPI values range between 0 and 1. Then, quartile method was used to categorise all non-zero BPI scores and the categories are as follows: 'Top priority' was assigned to 'fourth quartile', 'high priority' was given to 'third quartile', 'medium priority' to 'second quartile' followed by 'low priority' to 'first quartile'. 'No priority' was assigned for states with 'BPI score of zero'.

Data used for calculations in the study were taken from various primary sources (Table 2) like official websites and reports published by government institutes; and wherever required, from secondary sources.

Table 1. Variables of BPI and their estimation procedures

Procedure	Formula
Rescaling of variables	$Rescaled\ value\ (r) = \frac{Actual\ value - Minimum\ value}{Maximum\ value - Minimum\ value}$
Production sub-index (PSI)	$PSI = [(\frac{1}{2} * per\ capita\ area\ harvested)^r + (\frac{1}{2} * share\ of\ area\ allocated\ to\ crop)^r] * (1 - export\ share)^r$
Consumption sub-index (CSI)	$CSI = [(Consumption\ per\ capita\ per\ year)^r] * (1 - import\ dependency\ ratio)^r$
Micronutrient deficiency sub-index (MDSI)	$VADSI = \left[\left(\frac{1}{2} * Proportion\ of\ preschool - age\ children\ with\ retinol < 20\frac{\mu g}{dl}\right)^r + \left(\frac{1}{2} * DALY\ sper 100{,}000\ in habitants\ due\ to\ diarrhoeal\ disease\right)\right]$
	$ZADSI = (\frac{1}{2} * Proportion\ of\ population\ at\ risk\ of\ inadequate\ zinc\ intake)^r + (\frac{1}{2} * Prevalence\ of\ stunting)^r$
Biofortification priority index (BPI)	$BPI = \sqrt[3]{PSI * CSI * MDSI}$

Source: Authors compilation

Table 2. Variables and data sources of the sub-indices

Sub- index	Variable	Variable explanation	Main data source and year
Production sub-index (PSI)	Share of area harvested (%)	Total area harvested of the crop(ha)/ net sown area of a state (ha)	Indiastatagri.com 2016, 2017, 2018 average
	Per-capita area harvested (ha)	Total area harvested of the crop(ha)/ total population in the state	Indiastatagri.com 2016, 2017, 2018 average censusindia.gov. in 2011
	Export share	If production is greater than 0 – Export share = Exports/(Production + imports); otherwise export share is 0%	Expert survey
Consumption sub-index (CSI)	Per-capita food consumption	Per-capita of the crop supply (kg/year)	NSS 66th round 2009–2010
	Import share	If production is greater than 0 – Import share = Imports/(Production + imports – exports); otherwise import share is 100%	Expert survey
Vitamin A deficiency sub-index (VADSI)	Serum retinol concentration <20 µg/dl	Proportion of preschool-age children with retinol <20 µg/dl	CNN Report 2016–18
	Disability-adjusted life years (DALYs)	DALYs per 100,000 inhabitants in a state due to diarrhoeal disease	ICMR, PHFI, and IHME
Zinc deficiency sub-index (ZDSI)	Inadequate zinc	Percentage of population at risk of inadequate zinc intake	CNN Report 2016–18
	Stunting zinc	Prevalence of stunting among children age < 5 years	

Source: Authors compilation

The results of the analysis were as follows. As we can see from table 3, top priority states for vitamin A enriched maize intervention are Himachal Pradesh, Jammu & Kashmir, Arunachal Pradesh, Madhya Pradesh, Gujarat, Jharkhand followed by Sikkim. Top priority states for zinc enriched maize intervention are Himachal Pradesh, Jammu & Kashmir, Arunachal Pradesh, Sikkim, Madhya Pradesh, Gujarat followed by Rajasthan. In case of Vitamin A enriched banana intervention, the states with highest potential include Mizoram, Kerala, Tripura, Andhra Pradesh, Karnataka, and Assam. The top priority states for vitamin A enriched cauliflower intervention are Chhattisgarh followed by Haryana, Jharkhand, Odisha, Madhya Pradesh, Gujarat and Punjab.

In the medium and low and priority states, following activities should focus on production and consumption of biofortified crops, they can be included in the existing programmes run by governments like Rastriya Krishi Vikas Yojana. Awareness programmes can be taken up on large scales to educate masses about biofortified crops and food. Biofortified crops like cauliflower and banana can be swapped in for mid-day meals and in Anganwadi centres to reach the target group. Civil societies and community kitchens should be encouraged to use biofortified food crops in their festive occasions.

CONCLUSION

In this study we identify priority states in India were biofortified maize, cauliflower and banana can be promoted. Combating Vitamin, A and zinc deficiency in the community can be expediated by utilizing the stockpile of Maize, Banana and Cauliflower through the biofortified variants. It is important to develop Vitamin A enriched Banana suitable to Indian agro climatic conditions which can be a cheap source of vitamin A. The most straightforward way ahead is combining and utilizing the maize, banana and cauliflower producing resources. Biofortified varieties can aid in eradicating the deficiencies in the country. Thereby, strengthening and promoting the nutritional security of the country. To address prevailing vitamin A deficiency and Zinc deficiency in India the biofortified maize, cauliflower and banana should be promoted in top and priority states. This study will aid policymakers and other stakeholders in devising interventions by responding to the situation with respect to the three dimensions of the Priority index.

Table 3. State wise BPI scores and rank for Maize, Banana & Cauliflower

State	Maize		Maize		Banana		Cauliflower	
	AMBPI score	Rank	ZnMBPI score	Rank	ABBPI score	Rank	ACBPI score	Rank
Andhra Pradesh	0.033	21	0.035	23	0.236	4	0.030	22
Arunachal Pradesh	0.265	3	0.307	3	0.167	8	0.107	18
Assam	0.000	-	0.000	-	0.186	6	0.183	12
Bihar	0.150	9	0.162	9	0.102	15	0.185	11
Chhattisgarh	0.087	12	0.090	14	0.110	13	0.435	1
Gujarat	0.230	5	0.283	6	0.167	9	0.234	6
Haryana	0.025	25	0.026	25	*	-	0.399	2
Himachal Pradesh	0.322	1	0.559	1	0.027	21	0.193	10
Jammu & Kashmir	0.291	2	0.384	2	*	-	0.142	15
Jharkhand	0.182	6	0.176	8	0.054	20	0.326	3
Karnataka	0.082	13	0.115	12	0.201	5	0.024	24
Kerala	0.002	26	0.002	26	0.325	2	0.019	26
Madhya Pradesh	0.244	4	0.286	5	0.097	17	0.248	5
Maharashtra	0.051	17	0.072	16	0.135	11	0.107	17
Manipur	0.038	19	0.047	20	0.16	10	0	27
Meghalaya	0.064	15	0.107	13	0.103	14	0.130	16
Mizoram	0.152	8	0.117	11	0.361	1	0.163	14
Odisha	0.031	22	0.035	24	0.115	12	0.299	4
Punjab	0.111	10	0.130	10	0.020	22	0.226	7
Rajasthan	0.093	11	0.239	7	0	-	0.063	20
Sikkim	0.170	7	0.300	4	0	-	0.178	13
Tamil Nadu	0.030	24	0.037	22	0.178	7	0.023	25
Telangana	0.055	16	0.052	18	0.100	16	0.030	21
Tripura	0.035	20	0.038	21	0.287	3	0.208	8
Uttar Pradesh	0.065	14	0.073	15	0.096	18	0.028	23
Uttarakhand	0.048	18	0.054	17	*	-	0.196	9
West Bengal	0.031	23	0.051	19	0.072	19	0.106	19

Top priority | High priority | Medium priority | Low priority | No priority

AMBPI- Vitamin A enriched Maize Biofortification priority index. *Data not available

ZnMBPI- Zinc enriched Maize Biofortification priority index. - Rank not assigned

ABBPI- Vitamin A enriched Banana Biofortification priority index.

ACBPI-Vitamin A enriched Cauliflower Biofortification priority index.

Source: Authors compilation

Authorship contribution :

First author conceptualization, methodology, writing – original draft. Second author validation and analysis. Third author writing – review & editing and Furth author supervision, visualization, and editing.

Declaration of competing interest:

The authors affirm that they have no known competing interests that could have appeared to influence the work reported in this paper.

Data availability:

The data utilised in this paper is available in the public domain and if demanded will be made available.

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