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Biofortification to combat Vitamin A deficiency sustainably through promoting Orange-fleshed Sweet Potato in eastern Uttar Pradesh

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ABSTRACT

India is among top few countries for Vitamin A deficiency as 60,000 children go blind annually. Other than blindness, a number of eye diseases like night blindness, bitot spot, xerothalmia and others are caused by vitamin A deficiency. More than 6% children in Uttar Pradesh suffer from clinical vitamin A deficiency. Vitamin A deficiency among poor children in Gorakhpur average to 42% (as high as 65% in 3 year age group). Government of India, supported by CIDA, Helen Keller International, Micro-nutrient Initiative, UNICEF, USAID and the World Bank distributed free vitamin A capsule. Results were positive and dramatic but met failure due costs involved, problem in distribution, and corruption. Sustainable solution with no costs to government is popularization of Orange Fleshed Sweet Potato (OFSP) varieties, which have yellow or orange flesh due to very high level of â-carotene (precursor of Vitamin A). OFSP also supply required quantity of Potassium, dietary fibre, and energy. OFSP produces more edible energy per unit and people can grow, store and consume throughout the year. Supported by Tata Trusts since last 3 years, PRDF tested more than 50 OFSP varieties and identified ST-14, CIP-440127 and VA-43 adapted to the region now popularizing its growing and consumption enjoining hundreds of farmers and thousands of school children. A cycle of multiplying healthy vines has been perfected and being practiced. A number of products of leaf and tuber like Pakora, chips, juice etc have been developed. More needs to be done on research and awareness fronts.

1. INTRODUCTION

1.1. Malady of Vitamin a Deficiency

Vitamin A deficiency is one of the most damaging forms of undernourishment (WHO, 1996). Among infant and children vitamin A deficiency results into eye problem and blindness. An estimated 190 million pre-school children and 90 million pregnant women are affected globally. In India 60,000 children go blind each year due to vitamin A deficiency (www.microneutrient.org). Other than complete blindness, a number of eye diseases like night blindness, partial blindness, bitot spot, Xerothalmia, stunting, inadequate energy uptake, subnormal functioning of the immune and reproductive systems are caused by vitamin A deficiency. More than 6% children in Uttar Pradesh suffer from clinical vitamin A deficiency, which is highest even among Indian states.

Regarding malady of vitamin A deficiency, India is lumped with African countries while the developed world is almost free of it. Medical College Gorakhpur did excellent studies during 1985 – 1998. Gupta (1987) estimated the prevalence of vitamin A deficiency in different age groups at Gorakhpur, based on hospitalized children for diarrhoea related diseases (Table 1). Sharma (1985) estimated the prevalence of vitamin A deficiency among children of 3 – 5 years' age group of Gorakhpur at 10.97%. Night blindness in children observed was 5.5%, conjuctival xerosis in 15.74%, Bitot's spot in 4.72% cases with active corneal involvement in 14.94% children (Gupta, 1987). Kansal (1997) studied the prevalence of vitamin A deficiency among rural and urban population at Gorakhpur. Overall prevalence of vitamin A deficiency was 6.8% under 5 years of age and it was more prevalent in rural areas (9.3%) than urban areas (3.1%).

1.2. OFSP a Possible Solution for the Malady

Sweet potato (*Ipomoea batatas* L. Lam), the second most important root tuber of the world, but in India categorized as "poor man's food" or "famine crop", has tremendous potential to contribute to a food based approach to promote food and nutrition security. It has diverse range of positive

Table 1. Vitamin A deficiency among hospitalised children suffering with diarrhoea in Medical College Gorakhpur (Gupta, 1987)

Age group	Children suffering from vitamin A deficiency
2 month-1 year	10%
1-2 year	43.3%
2-3 year	45.8%
3-4 year	61.9%
4-5 year	53.8%
5-6 year	55.3%
Average	**40.9%**

attributes like high yield with limited inputs, short duration, high nutritional value and tolerance to various biotic and abiotic stresses. Orange-fleshed sweet potato (OFSP) is now emerging as an important type of sweet potato to tackle the problem of vitamin A deficiency (Mukherjee *et al.* 2003). Apart from being rich source of vitamin A in the form of β-carotene (Table 2), benefits may also occur from other health enhancing features of sweet potato like adequate calories, vitamin C, vitamin D and micronutrients such as iron and zinc. The various preparations of OFSP tubers and tender leaves and vine could also be eaten (Chaudhary, *et al.* 2015b). Thus, the poor people having only limited access to the expensive vitamin A rich animal foods like fish oil, egg, and cow milk or plant products like papaya, mango, carrot etc. can consume it. As a biofortified crop many African countries are using it to alleviate Vitamin A malnutrition (CIP 2015).

Orange-fleshed Sweet Potato (OFSP) is potential solution and (Purcell and Walter, 1968; Simonne *et al*., 1993; Takahata *et al*., 1993; Mukherjee *et al.* 2009; and Laxminarayana, 2013) with rich β-carotene, which is converted to vitamin A by the human body.). 100 g of sweet potato may supply enough â-carotene to satisfy 0 to 100% of the daily-required amount of vitamin A, depending on the â-carotene content of the sweet potato variety used (Mukherjee *et al.* 2009). It is estimated that 300-450 micro-gram equivalents of retinol per day satisfy the daily requirements for infants up to 10 years old, which is equivalent to about 2100-2400 micro-grams of β-carotene. Usually a ratio of 4:1 to 8:1 is used to convert β-carotene into retinol since not all β-carotene can be converted by the human body. Therefore 100-120 g of a yellow flesh sweet potato containing 2500 micro-gram/100 g fresh weight of β-carotene is adequate to meet the daily requirement of Vitamin A (Tsou and Hong 1992). Regular intake of 100g per day orange-fleshed sweet potato roots provides the recommended daily dose of vitamin A for children (Hagenimana and Low, 2000, Low *et al.* 2001, Mitra, 2012).

2. MATERIALS AND METHODS

Available exotic and indigenous cultivars of OFSP were

Table 2. Nutritional value of Golden Sweet Potato (per 100 g of fresh tuber); mg = milligram; % indicates daily dietary requirement of an adult (Data source: USDA 2012, CTCRI, 2014).

Nutrient	Value	Nutrient	Value
Energy	359 kJ (86 kcal)	Sugars	4.2 g
Carbohydrate	20.1 g	Dietary fibre	3 g
Starch	12.7 g	Fat	0.1 g
β-carotene	20 mg (283%)	Protein	1.6 g
Thiamine (B1)	0.078 mg (7%)	Calcium	30 mg (3%)
Riboflavin (B2)	0.061 mg (5%)	Iron	0.61 mg (5%)
Niacin (B3)	0.557 mg (4%)	Magnesium	25 mg (7%)
Pantothenic acid (B5)	0.8 mg (16%)	Manganese	0.258 mg (12%)
Vitamin B6	0.209 (16%)	Phosphorus	47 mg (7%)
Folate (B9)	11 ug (3%)	Potassium	337 mg (7%)
Vitamin C	2.4 mg (3%)	Sodium	55 mg (4%)
Vitamin E	0.26 mg (2%)	Zinc	0.3 mg (3%)

Table 3. Baseline survey of vitamin A deficiency in the project area in Gorakhpur and Sant Kabir Nagar districts (Dr. Anita Khan and Dr. K. P. Singh) project Area in November, 2015

	Gorakhpur: Ramnagar – Karjaha				Sant Kabir Nagar: Kataya Primary School			
Age Group	Beneficiaries + Students	Normal	Bitot Spot	VAD	Primary Student	Normal	Bitot Spot	VAD
00 – 10	67	47	20	-	118	45	2	71
11 – 20	10	7	3	-				
21 – 40	52	14	-	38				
41 – 60	31	17		14				
61- Ab.	2	1	0	1				
Total	162	86 (53%)	23 (14%)	53 (33%)	118	45 (38%)	2 (1%)	71 (60 %)

tested in two locations during Kharif 2014-15 and Kharif 2015-16 in randomized block design with two replications. Plot size for each test entry was 2.5m X 1.35 meters = 3.375 m^2 and normal crop care was taken. The crop was dug out after 120 days and tuber yield (kg/plot) was recorded. After washing, peeling and slicing 100 gram tubers of each test variety were dried at 70°C for about 48 hours to determine the dry matter content. The prevalence of Vitamin A deficiency was surveyed in the project areas in Gorakhpur and Sant Kabir Nagar districts of eastern U.P. using qualified Ophthalmologists. They based their observations on the presence of "Bitot Spot" and general symptoms Vitamin A Deficiency (VAD). School children and beneficiaries were examined for it to create a baseline.

3. RESULTS AND DISCUSSION

3.1. Baseline survey for Vitamin A deficiency

To create a baseline of current status of vitamin A deficiency in the project a survey was conducted in Gorakhpur and Sant Kabir Nagar districts. Beneficiaries and school, children were examined by qualified ophthalmologists. Though the period conceded with the season when green leafy vegetables are consumed maximum, still the vitamin A deficiency was noticeable (Table 3) in form of Bitot's Sport and Vitamin A Deficiency syndrome (VAD). It was surprising to note that in Ramnagar Karjahan primary school, 23% children were spotted with Bitot's Spot and 33% with VAD. In Kataya Primary school though Bitot Spot was only 1% yet 60% children were diagnosed with VAD.

3.2. Varietal introduction and testing

During the years 2003 to 2005 more than 50 varieties were introduced through CIP New Delhi office and tested by PRDF in farmers' fields but none of these were found to have acceptable level of yield and â-carotene. Thus these were rejected and the project was halted. After due verification trials a manual on cultivation of OFSP was developed (Chaudhary *et al.* 2015a). During the year 2014 out of 11 breeding lines and varieties tested at 2 locations ST-14, PRDFS-1, PRDFS-2, Shree Kanaka, CIP440127 and Gauri yielded satisfactory (Table 4). Significant variations in yield of the tubers were observed among the genotypes of orange-fleshed sweet potato (Table 4). Based on the yield NCS and β-carotene content ST-14, Shree Kanaka, PRDFS-1 and CIP440127 were repeat tested during Kharif 2015 along with the new introductions (Table 5). Kharif 2015 was drought year thus yield levels were low yet ST-14, CIP440127 and VA43 showed promise. These varieties were selected for further multiplication and distribution among farmers.

3.3. Popularising OFSP

Sweet potato can be grown three times annually using the poor soils and rainfed agriculture. In the selected villages farmers are well aware of sweet potato growing. Thus introduction of OFSP simply meant change of the variety. Sweet potato weevil is the most serious pest, which was controlled by supplying pest free planting material. Nurseries and multiplication systems have been developed (Chaudhary *et al.* 2015a) using farmers in varied locality to produce maximum quantity of planting material. Farmers

Table 4. Yield (kg / plot) of OFSP test varieties at two locations in Gorakhpur and Sant Kabir Nagar districts, 2014 – 2015

S. N.	Variety	Gorakhpur: Ramnagar Karjahan	Sant Kabir Nagar: Khairgar
1	ST-14	2.705	8.268
2	ST-13	0.032	1.075
3	PRDFS-1	4.099	14.518
4	Ranchi local	3.901	17.568
5	Shree Kanaka	2.245	7.299
6	CIP-440127	5.558	44.643
7	PRDFS-2	2.047	6.047
8	Gauri	3.816	7.975
9	PRDFS-3	0.999	1.65
10	Local Hybrid	0.0	10.188
11	Local White	6.048	2.446
	CD	1.131	4.188

were trained and demonstrations were done on their fields. Most importantly a system of round the year cultivation and variety multiplication using normal land to river beds and riversides were amalgamated for moving around the planting for making available the planting materials. A system of using vine multipliers was developed by supplying them clean planting material grown in project's screen houses.

3.4. Product and Production

Schools were chosen as the entry points for popularization of the new product as the trained girls will prepare at their homes and the chosen product will move from home to homes and village to village. OFSP product development entrepreneurs and whole sellers are vital to the profitability of the beneficiaries. In shortest run it will encourage some ladies to produce commercial quantity of the products and local entrepreneurs will develop for Orange fleshed sweet potato products. A total of 15 of products using leaves (*pakora*, green vegetable) and tubers (chips, cutlets, *gulab jamun*, *halwa*, jam, juice, *kheer*, noodles, pickle, *sabji*, salty fries, *samosa*, sauce sweet dimons, and sweet fries) were developed (Chaudhary *et al.,* 2015b). Home Science students in the local intermediate colleges were trained (Table 6). This made excellent entry point for the new products to become popular. More needs to be done on research and awareness front.

4. CONCLUSIONS

Malady of Vitamin A is rampant in eastern part of U. P. and awareness need to be generated about its ill effects and ways to ameliorate through consuming OFSP. Many breeding lines were introduced and tested for 2 years in Gorakhpur and Sant Kabir Nagar districts of U. P. Superior

Table 5. Yield (kg / plot) of test varieties at two locations in Gorakhpur and Sant Kabir Nagar district, 2015 – 2016

S. N.	Variety	Gorakhpur: Ramnagar Karjahan	Sant Kabir Nagar: Khairgar	Dry Matter in tubers
1	CIP 440127	2.084	10.145	18.23
2	VA 43	1.849	6.122	18.97
3	VA 44	0.413	3.046	19.69
4	ST-14	1.718	2.886	28.55
5	Shree Kanaka	0.951	0.00	23.52
6	Local Red	0.156	0.061	-
7	Kanpur Hybrid	0.046	3.248	-
8	PRDFS-1	0.211	0.653	22.42
9	GSP-15	0.118	0.614	-
10	Ujjawal	0.00	1.587	25.42
11	Roshani	0.065	00	-
	CD	0.308	0.905	-

Table 6. Farmers participated and students trained during 2014 - 2016

District	2014-15		2015-16		Total
	Farmers participated	Students trained	Farmers participated	Students trained	
Gorakhpur	54	86	140	48	140
Sant Kabir Nagar	53	58	94	250	455
Total	107	141	234	298	595

ones like ST-14, CIP 440127, VA 43, and PRDF S1 were identified and being distributed to farmers on large scale. System of vine multiplication was streamlined to supply healthy planting material on a sustainable basis. More than 300 farmers were involved. Introducing a marginal change in the diet like switching varieties is likely to be easier than introducing a completely new food. Thus, replacing the white-fleshed sweet potato varieties consumed with new OFSP cultivars like ST-14, CIP 440127, VA 43, and PRDF S1 having high â-carotene would be helpful in alleviating vitamin A deficiency. Production of OFSP was linked to consumption by developing 15 different products in addition to roasting and boiling to promote in diets. Awareness generation among masses and training of school students on Vitamin A malnutrition *vis-a-vis* different food products of OFSP was generated. Sustainable and cheapest solution to combat vitamin A deficiency is through the use of Orange fleshed Sweet Potato (OFSP) or Sunhri Shakarkand (Golden Sweet Potato). Many African and Latin American countries where Vitamin A deficiency is severe are promoting use of OFSP and have strong research and development projects for it. India must follow the same path if it has to eradicate Vitamin A deficiency by biofortification. Once with the farmers, no cost is involved to the government, and no room for corruption and mismanagement.

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