SEMINAR REPORT

‘Breeding crops for better nutrition’

By

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(2018-11-176)

Presented on 21-12-2019

Submitted in partial fulfilment of requirement of the course

GP 591: Master’s Seminar (0+1)

DEPARTMENT OF PLANT BREEDING AND GENETICS

COLLEGE OF HORTICULTURE

KERALA AGRICULTURAL UNIVERSITY

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2020

DECLARATION

I, Maqsoodullah (2018-11-176) declare that the seminar entitled **'Breeding crops for better nutrition'** has been prepared by me, after going through various references cited at the end and has not been copied from any of my fellow students.

Vellanikkara Maqsoodullah

25/01/2020 2018-11-176

CERTIFICATE

This is to certify that the seminar report entitled **'Breeding crops for better nutrition'** has been solely prepared by Maqsoodullah (2018-11-176), under my guidance and has not been copied from seminar reports of any seniors, juniors or fellow students.

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1. Introduction

Malnutrition is one of the most serious problem in the world, especially in developing countries will never lead healthy, happy lives due to 'hidden hunger' caused by an inadequate intake of nutrients. The United Nations Food and Agriculture Organization has estimated that around 792.5 million people across the world are malnourished, out of which 780 million people live in developing countries. Apart from this, around two billion people across the world suffer from another type of hunger known as "hidden hunger," which is caused by an insufficient amount of essential nutrients in their daily diets and foods (McGuire, 2015).

Now, agriculture is undergoing a shift from producing more quantity of food crops to producing nutrient-rich food crops in sufficient quantities. This will help in fighting 'hidden hunger' or 'micronutrient malnutrition' especially in poor and developing countries, where diet is dominated by micronutrient-poor staple food crops (Garg *et al.*, 2018).

Biofortification is a process of increasing the density of vitamins and minerals in a crop through plant breeding, transgenic techniques, or agronomic practices to fight hidden hunger especially in developing countries (Garg *et al.*, 2018). Biofortified varieties of rice, wheat, maize, pearl millet, common bean, banana *etc.* were developed to support our nutritional stability (Steur *et al.*, 2012).

Enhancement of nutritional quality of crops with higher mineral content through breeding is one of the most cost effective method to solve the global mineral malnutrition Bouis and Saltzman,. 2017). Biofortified cultivars are being developed through conventional breeding. Hence, produce from such cultivars will not face the possible challenge of food regulations and consumer acceptance.

2. **Importance of better nutrition**

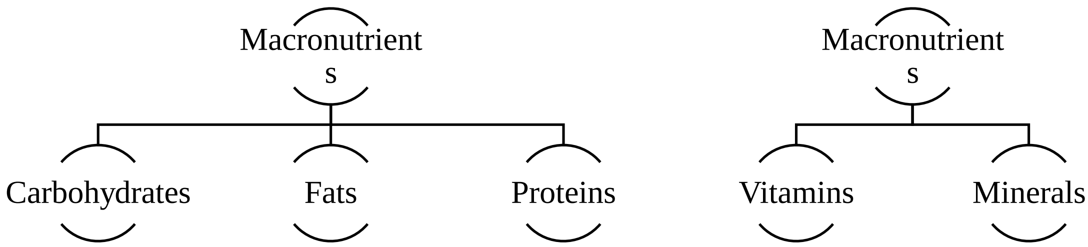
Most people know good nutrition and physical activity can help maintain a healthy weight. But the benefits of good nutrition go beyond weight. The advantages of better nutrition is the following:

1. Reduce the risk of some diseases, including heart disease, diabetes, stroke, some cancers, and osteoporosis
2. Reduce high blood pressure
3. Lower high cholesterol
4. Improve your well-being
5. Improve your ability to fight off illness
6. Improve your ability to recover from illness or injury
7. Increase your energy level

3. **Nutrients**

There are two main categories of nutrition (Chandna, 2011).

- Nutrients that build tissue and provide energy
- Nutrients that help our body to run smoothly



Carbohydrate

- Best fuel – provide energy quickly and efficiently and they are Two types:

Simple sugars

- Glucose (monosaccharide) – most common form
- Fructose (monosaccharide) – found in fruits and berries

- Sucrose (disaccharide) – sources include granulated sugar, milk and milk products

Complex carbohydrates (polysaccharides)

- Starches – from flour, pasta, potatoes
- Stored in the body as glycogen
- Fiber

Fats

Also called lipids, misunderstood but vital group of basic nutrients

- Maintain healthy skin
- Insulate body organs
- Maintain body temperature
- Promote healthy cell function
- Carry fat-soluble vitamins A, D, E, and K
- Are a concentrated form of energy

Protein

- Proteins are complex organic nitrogenous compounds
- They also contain sulfur and I, some cases phosphorus and iron
- Proteins are made of monomers called amino acids
- There are about 20 different amino acids which are found in human body
- Of this 8 amino acids are termed ‘essential’ as they are not synthesized in human body and must be obtained from dietary proteins

Vitamin

- Vitamins are a class of organic compounds categorized as essential nutrients. They are required by the body in a very small amounts. They fall in the category of micronutrients.
- Vitamins are divided in to two groups: fat soluble vitamins- A, D, E and K and water soluble vitamins: vitamins of the B-group and vitamin C.
- 'Vitamin A' covers both a pre-formed vitamin, retinol, and a pro-vitamin, beta carotene, some of which is converted to retinol in the intestinal mucosa.

Mineral

- Inorganic compounds not synthesized by the body
- Needed in very small quantities but possibly essential
- Important for biochemical processes and formation of cells and tissues

Table 1: Nutritional content of cereals grains

Grain	Protein %	Carbohydrate %	Fat%
Wheat	13.5	60.0	1.9
Rice	7.1	78.5	0.7
Maize	6.9	69.0	4.0
Barley	12.5	63.6	2.3
Millet	11.0	64.4	4.2
Sorghum	11.3	68.3	3.3

(Chandna, 2011)

Table 2: Nutritional content of legumes

	Common name	Protein%	Carbohydrate%	Fat%
Fresh legumes	Shelled lima bean	7.1	22.0	0.7
	Shelled peas	7.0	16.9	0.5
	String bean	2.3	7.40	0.3
Dried legumes	Lima beans	18.1	65.9	1.5
	Dried Peas	24.6	62.0	1.0
	Soybeans	34.0	33.7	16.8
	Peanuts	25.8	24.4	38.6

Table 3: Nutritional content of vegetables

Common name	Protein %	Carbohydrate %	Fat%
Onion	1.60	9.90	0.30
Lettuce	1.20	2.90	0.30
Tomato	0.90	3.90	0.40
Cauliflower	1.62	4.90	0.79
Okra	1.99	6.40	0.40
Carrot	1.10	8.20	0.40

(Chandna, 2011)

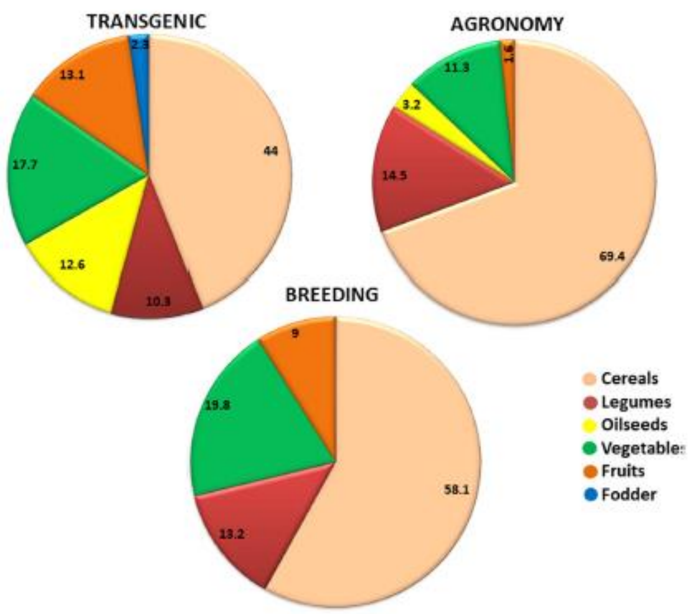
Table 4: Nutritional content of fruits

Common name	Protein %	Carbohydrate %
Apple	0.4	14.2
Banana	1.3	22.0
Orange	0.8	11.6
Date	2.1	78.4
Lemon	1.0	8.5
Pear	1.0	17.2

(Chandna, 2011)

4. Improvement of nutritional quality of crops

The manuscript deals in all aspects of crop biofortification which includes- breeding, agronomy, and genetic modification (Sharma *et al.*, 2018).



Figure, 1: Representation of reported biofortified crops by transgenic, agronomic, and breeding means. (A) Comparison of transgenic and breeding approaches of biofortification in terms of relative research and release of commercial crops. While higher emphasis is being laid on transgenic-based biofortification, success rate in terms of cultivar release is higher for breeding-based approach. (B) Percentage of different crops biofortified by different approaches. Cereals have been biofortified in largest number by all three biofortification approaches. Legumes and vegetables have also been targeted by all the approaches in almost equal percentage. Transgenic approach covers highest number of crops. Oilseed crops have been mainly targeted by transgenic approaches due to limited genetic variability.

5. Improvement of iron and zinc in rice

Kumar and his colleague conducted an experiment in 2018, and crossed PAU201 (high yielding) with Palman 579 (iron rich) content as the following method:

PAU201 : High yield, low Fe and Zn

Palman 579 : Low yield, high Fe and Zn

BC1F2 population (466 plants)

BC1F3 population (106 plants)

PAU201 × Palman 579 ⟶ F_1
Backcross (PAU201 X F_1) ⟶ BC_1F_1
Evaluation of BC_1F_2 raised from selected BC_1F_1 plants
Evaluation of BC_1F_3 population

Table 5: Result of cross between PAU201 × Palman 579

Name	Iron (µg/g)	Mean (µg/g)	Zinc (µg/g)	Mean (µg/g)
BC1F2	0.9-101.7	32.5	0.8-143.1	21.0
BC1F3	17.1-130.5	40.7	9.6-27.2	18.5
PAU201	53.9±0.3		16.3	
Palman579	378.5±0.4		22.3	

(Kumar *et al.*, 2018)

6. Improvement of zinc in wheat

Virk and Govindan in 2014, screened more than 3,000 germplasm accessions by the International Maize and Wheat Improvement Center (CIMMYT) found ranges of 20 -115 ppm zinc in wheat, with the highest levels found in landraces; high-zinc genotypes were selected to initiate crosses (Xu *et al.*, 2010). Multi-environment testing was conducted to evaluate the most promising germplasm and verify that mineral accumulation was stable across sites and generations. And they selected 100-150 promising advanced lines in each year, based on grain yield and grain zinc, for testing in genotype-by-environment (GxE) trials for agronomic attributes and grain zinc at 10–15 sites.

Table, 6: Released varieties of wheat

Variety name	**Zinc increase**	**Yield**	**Duration**	
			Days to heading	**Days to maturity**
BHU1	+4-10 ppm	5.0 t/ha	84	126
BHU3	+6-8 ppm	4.4 t/ha	83	125
BHU5	+4-5 ppm	3.3 t/ha	86	128
BHU6	+4-9 ppm	3.4 t/ha	78	119
BHU7	+6-10 ppm	4.1 t/ha	81	122
BHU18	+6-9 ppm	3.9 t/ha	87	131

(Virk and Govindan., 2014)

Achievements:

- 4-8 ppm increase in Zinc
- 33-66% target increment, India, 2014

7. Improvement of Fe and Zn in common bean

Six parental materials were crossed following full Diallel mating design at the Rwerere station in Northern Agricultural Zone Division.

- CAB2 X LAS 400
- CAB2 X BUBERUKA
- NGWINURARE X CAB2
- ANDx X UMWIZARAHENDA

Table 7: Result the above crosses in common bean

Variety	**Df**	**Dm**	**Seed colour**	**Seed size**	**Fe content (mg/g)**	**Zn content (mg/g)**	**Yield (kg/ha)**
RWV3317	56	110	Red	L	95	28	4000
RWV 3316	58	110	Red	L	92	31	4000
RWV2872	56	108	Sugar	L	85	29	4200
RWV 3006	58	110	White	L	84	35	3800
RWV 2361	57	108	Sugar	L	78		3800

(Butare *et al.*, 2015)

8. Improvement of Fe in pearl millet

All the pearl millet hybrids so far developed in India are based on cytoplasmic male sterility (CMS). Currently A line (male sterile line) with high Fe content crossed with high Fe R line (restorer line) resulted in hybrid with high Fe content, which was selected based on evaluation in on-farm trails (Govindaraj *et al.*, 2019).

High – Fe, A line × High – Fe, B line

↓

High – Fe, F_1

↓

On-farm trail

↓

Release

Figure, 2: Biofortified hybrids released in India > 70 mg/kg Fe

ICMH 1202 (AHB1200)   ICMH1202 (HHB299)   ICMH 1301 (DHBH1211)

9. Improvement of vitamin-A in maize

Objective: To increase the amount of vitamin-A from zero to 15 ppm through breeding programme in the following (Table, 8).

Target Micronutrient	Vitamin A
Baseline (ppm)	0 ppm
Target increment	+15 ppm
Target level in crop	15 ppm

Dhliwayo in 2014, screened more than 1,500 maize germplasm accessions found ranges of 0–19 ppm provitamin A in existing maize varieties. Natural genetic variation in some lines exceeded the trial average by at least 60 percent for beta-carotene and provitamin A. These nutrients were consistently expressed in the maize inbred lines across different growing conditions, and further assessment indicated potential to increase the levels of multiple carotenoids simultaneously.

And they released the following varieties in the Table, 9).

Release Name	**Overall Average Yield**	**Provitamin-A Content**
Zambia – Released in 2012		
GV664A	4.46 t/ha	+7 ppm
GV665A	3.85 t/ha	+8 ppm
Nigeria – Released in 2012		
Ife maizehyb-3	5.74 t/ha	+8 ppm
Sammaz 38 (OPV)	3.54 t/ha	+6 ppm

Achievements:

- 6-8 ppm increase in Vitamin-A
- 40-60% target increment, 2012

10.Improvement of vitamin-A banana/plantain

Objective: To increase the amount of vitamin-A from 10-18 ppm to 58 ppm through breeding programme in the Table, 10).

Target micronutrient	**Vitamin A**
Baseline (ppm)	10-18 ppm
Target Increment	+58 ppm
Target Level in Crop	17-106 ppm

Ekesa in 2014, screened more than 3000 genotypes and found 1–345 ppm provitamin A in existing banana/plantain varieties. Carotenoid content was indicative of pulp color, and maximum values for provitamin A carotenoids (pVACs) were discovered in African varieties. Then he selected 400 accessions from different regions screened.

The following varieties Table, 11), released and Selected for Dissemination in Eastern and Burundi:

Variety name	**Country origin**	**Genome sub group**	**Fruit ripening stage**	**Total carotenoid**
Apantu	Ghana	AAB-Plantain	Unripe	46.83 ppm
			Ripe	100.71 ppm
Bira	Papua New Guinea	AAB-Pacific plantain	Unripe	43.42 ppm
			Ripe	106.38 ppm
Pelipita	Philippines	ABB-Plantain	Unripe	25.35 ppm
			Ripe	17.44Pm

11.Conclusion

Breeding is the most accepted method for improvement of nutritional quality of crops to reduce the deficiency of essential elements in daily diets of population in developing countries. It offers a sustainable, cost-effective and easy method for producing of sufficient nutrient with desirable traits. (Garg *et al*., 2018).

Breeding programs can utilize the various genotypes to improve the levels of minerals and vitamins in crops. In conventional plant breeding, parent lines with high nutrients are crossed with recipient line with desirable agronomic traits over several generations to produce plants with desired nutrient and agronomic traits.

Breeding can improve nutritional value of foods. Genetic diversity and plant breeding are the key elements in enhancing the value of crops for improving nutrition. In some cases, this can be overcome by crossing to distant relatives and thus moving the trait slowly into the commercial cultivars. Alternatively, new traits can be introduced directly into commercial varieties by mutagenesis.

Breeding is directed to produce staple food crops with enhanced levels of bioavailable essential minerals and vitamins that will have measurable impact on improving the micronutrient status of target populations, primarily resource-poor people in the developing world.

12. Discussion

1. Why the breeder want to improve the nutritional quality of crops especially staple crops?

   Because these are the crops which is used in high amount (in their daily diets) in developing countries, but they don't have sufficient elements for their activities, due that the breeders are arguing to enhance the amount nutrient in those crops.
2. How many methods or approaches are exist for improving nutritional quality of crops?

   Generally, there are three main approaches involve, agronomic practices, conventional plant breeding and transgenic or genetically modified plant approaches.
3. What is the difference between simple fortification and biofortification for improvements of nutritional quality of crops?

   Usually fortification is a process which used during food processing and essential nutrients added to the food, whereas biofortification is an approach that breeder struggle to enhance the nutritional value of crops during plants growth on the field.
4. Why we can't improve or develop oilseeds through breeding methods and they improve through transgenic?

   Because of lack of genetic variability and low heritability, oilseeds are usually targeted by transgenic approach.
5. Which types of nutrients will enhance through conventional breeding approach?

   Generally there are types of nutrients, and breeders wants to improve each of them according to the population malnutrition.

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Govindaraj, M., Rai, K. N., Cherian**,** B., Pfeier, W. H., Kanatti, A., and Shivade, H. 2019. Breeding biofortified pearl millet varieties and hybrids to enhance millet markets for human nutrition. *Agri.* 9(106):1-11.

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10. Abstract

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GP 591: Master's Seminar

Name	: Maqsoodullah	Venue	: Seminar Hall
Admission No	: 2018-11-176	Date	: 21-12-2019
Major Advisor	: Dr. Jiji Joseph	Time	: 09.15 am

Breeding crops for better nutrition

Abstract

Good nutrition is an important part of a healthy lifestyle. Combined with physical activity, diet will help to reach and maintain a healthy weight, reduced risk of chronic diseases, and promote overall health. Unfortunately, major food crops are poor sources of micronutrients required for normal human growth. The Food and Agriculture Organisation has estimated that around 792.5 million people across the world are malnourished, out of which 780 million people live in developing countries (McGuire, 2015). So far, our agricultural system has not been designed to promote human health; instead, it only focuses on increasing grain yield and crop productivity. Now, agriculture is undergoing a shift from producing more quantity of food crops to producing nutrient-rich food crops in sufficient quantities. This will help in fighting 'hidden hunger' or 'micronutrient malnutrition' especially in poor and developing countries, where diet is dominated by micronutrient-poor staple food crops (Garg *et al*., 2018).

Biofortification is a method to increase the nutritional value of crops, including increased content of micronutrients or their precursors. There are three approaches of biofortification; agronomic practices, conventional breeding and genetic modification (Garg *et al*., 2018). Biofortified varieties of rice, wheat,

maize, pearl millet, common bean, banana *etc.* were developed to support our nutritional stability.

Nutritional quality of crops can be improved by traditional breeding methods, provided sufficient genetic variation is available in crop germplasm. The backcross population developed from the parents, PAU201 and Palman 579 showed large variation for various physio-morphological traits and micronutrient (Fe and Zn) content in rice (Kumar *et al*., 2108). Pedigree selection improved Fe and Zn in common bean. X-Ray fluorescence mineral analysis was used to select the most promising advanced lines for Fe and Zn content (Butare *et al.,* 2015). Heterosis breeding resulted in high Fe content in pearl millet. All the pearl millet hybrids so far developed in India are based on cytoplasmic male sterility (CMS). Currently A line (male sterile line) with high Fe content crossed with high Fe R line (restorer line) resulted in hybrid with high Fe content, which was selected based on evaluation in on-farm trails (Govindaraj *et al.,* 2019).

Improvement of nutritional quality of crops with higher mineral content through breeding is one of the most cost effective method to solve the global mineral malnutrition. Biofortified cultivars are being developed through conventional breeding. Hence, produce from such cultivars will not face the possible challenge of food regulations and consumer acceptance.

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