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Development of Organic Vegetable Seeds for Climate Resilient Agriculture: A Path Breaking Exercise

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Abstract—*Climate smart agriculture as a part of climate change mitigation strategy starts with quality- resilient seeds suitable for organic and low input agriculture. The seeds developed under conventional farming are generally high fertilizer responsive, hence lack the quality traits viz. higher nutrient use efficiency, disease resistance and resilience against biotic and abiotic stress. In this context seed produced under organic environment could help out in infusing such quality traits that can enable better adaptability against climate change and support sustainable agriculture.*

A joint initiative by Nadia KVK, BCKV and Inhana Organic Research Foundation (IORF) was taken up to develop organic vegetable seeds. Ten different crop varieties were selected for the programme, viz.Brinjal, Chilli, Okra, Bitter, Pumpkin, Amaranthus Red, Beans, Cherry Tomato, Spinach and Bottle Gourd.

Quality of the organically developed seeds was compared with the Indian Minimum Seed Certification Standard (2013). Comparative quality analysis of conventional seeds vis- a - vis organically grown seeds was done in respect of three important aspects like seed viability, seed vigour and seed resilience under abiotic stress. Seed viability in terms of germination percentage and Tetrazolium (TZ) assay test showed comparatively higher in the case of organically developed seeds. Following a similar trend the organically grown seeds showed upto23.98 % higher value in seed vigour test when compared with the conventional seeds.

Evaluation of seed resilience under abiotic stress was the most important component of this experimental protocol to assess the adaptability potential of the organic seeds as compared to the conventional grown variants. The study comprised four testing criteria viz. Germination under water stress (G_{WS} %), Germination under salt stress (G_{SS} %), Germination under Accelerated ageing (G_{AA}%) and Electrical conductivity test to assess the seed membrane integrity. When compared in terms of the seed viability and seed vigour tests, 31.03 % higher values were obtained in the tests for seed resilience under abiotic stress with organically grown seeds. This indicates higher resilience against abiotic stress and storage potential, as compared to the conventional seeds.

Introduction

More than 95% of organic/low input agriculture is dependent on seed varieties that were bred for the conventional high input sector. Recent findings have sown that such varieties lack important traits required under organic and low–input production system, which have major importance towards climate change mitigation strategies [Van Bueren, 2011]. Especially the vegetable crops are highly sensitive to climatic vagaries, where sudden rise in temperature or irregular precipitation at any phase of crop cycle can affect growth, flowering, pollination and fruit development, which may subsequently lower the crop yield [Afroza *et al*., 2010]. To mitigate the adverse impact of climate change on the productivity and quality of vegetable crops there is need to develop sound adaptation strategies [Spaldon, 2015].

In this background, the present study was undertaken by Nadia Krishi Vigyan Kendra (BCKV), West Bengal to develop organic vegetable seeds with special emphasis on Soil and Plant Health Management through adoption of Inhana Rational Farming Technology – A Comprehensive Organic Package of Practice.

Materials and Methods

Organic vegetable seed development program was initiated in the Instructional Farm of Nadia KVK in collaboration with Inhana Organic Research Foundation (IORF), Kolkata in the year 2018.

Inhana Rational Farming (IRF) Technology: Inhana Organic Farming is a comprehensive organic approach towards ecologically and economically sustainable crop production. Inhana Organic Farming focuses on Energy Infusion or Energization of the two critical influential components of crop production i.e., Soil and Plant System.

Energization of soil system aims to reactivate the soil- plant microflora dynamics by providing an ideal environment and food source for natural regeneration of the population and functional abilities of the native soil microflora. This is primarily done through application of on-farm produced Novcom Compost as well as Soil Energizers prepared on- farm from cow based and locally available organic inputs. Along with this different cultural practices *viz*. mulching, in-situ composting, green manuring, cover cropping, etc. are also recommended as per specific requirement.

Energization of Plant System aims to energize, stimulate and reactivate the plants' physiological, metabolic and biochemical functions, through the scheduled application of 'Inhana Energy Solutions'. These solutions are the potentized and energized botanical extracts developed under Element-Energy-Activation (E.E.A) Principle.

Cultivation : Ten different crop varieties were selected for organic seed development *viz*.Brinjal (*Solanum melongena;* variety :Muktakeshi), Chilli (*Capsicum frutescens*L.;variety :Tiger Bullet), Okra (*Abelmoschus esculentus;* variety : Local), Bitter Gourd (*Momordica charantia;* variety :Megna–2), Pumpkin (*Cucurbita maxima;* variety :Halisahar Barsati), Amaranthus Red (*Amaranthus cruentus;* variety :Jabakusum Shak), Beans (*Phaseolus vulgaris;* variety :Simran P.G.), Cherry Tomato (*Solanum lycopersicum* var. cerasiforme*;* variety: Sheeja), Spinach (*Spinacia oleracea;* variety :local) and Bottle Gourd (*Lagenaria siceraria;* variety :Debjyoti).

Organic soil management was done primarily with application of Novcom compost [Seal et al, 2012] @ 15 ton/ha followed by application of enriched cow dung slurry prepared as per the guideline of IRF technology. Required seeds were collected from the recommended source and seeds were treated with IRF seed treatment solutions before sowing. Standard cultivation guideline [Singh and Bhatia, 2009] along with IRF Plant Health Management [Bera *et al*, 2014a] was followed strictly from seed sowing to harvesting.

Analysis of Seed Quality: Comparative evaluation of conventional and organic vegetable seed quality, viability, vigour as well as resilience under different abiotic stresses were evaluated with following standard methodologies.

Seed Germination percent was evaluated as per the methodology of AOSA (1992), whereas Germination Velocity index (GVI) was calculated based on Maguire's formula (Maguire, 1962). Seed viability with Tetrazolium (TZ) assay test was done according to the methodology of Wharton (1955). Seed vigour which refers to its activity level and performance during germination and seedling emergence was calculated as per the methodology of Abdul-Baki and Anderson (1973). Seed resilience was evaluated through germination under stress conditions *viz*. (i) water stress using D-Mannitol soak test [Lad, 1986], (ii) salt stress using Ammonium chloride/sodium chloride soak test [Vanderlip et al, 1978] and (iii) accelerated ageing [Delouche and Baskin, 1973]. Seed Electrical Conductivity Test [Presley, 1958] was done to examine the integrity of cell membranes, which is correlated with seed vigor.

Results and Discussions

Agronomic parameters of Vegetable seeds

Different agronomic parameters *viz.* height of the plants, leaves/plant, branches/plant, flowers/plant and fruits/plant was recorded 75 days post sowing (Table 1). The observation also documented that the plants were healthy, no sign of disease infestation or nutrient deficiency and negligible damage by any pest infestation. Flowering initiation followed by fruits started as per reference time period and did not show any abnormalities.

Quality Analysis of Vegetable Seeds

Quality seeds are of high species and cultivar purity (genetic purity); analytical (physical) purity; high germination capacity and vigour; uniform in size; free from weed seed; free from seed borne diseases; and low moisture content (3 to 7%). In the present study seed quality was primarily compared with the Indian Minimum Seed Quality Standard (2013) [Trivedi and Gunasekaran, 2013].

It is necessary to maintain correct moisture content of the seeds because those with high moisture content lose their germination vigour and viability within a short period of time. All the organically produced vegetable seeds contained moisture within stipulated range as per standard reference and well within the Indian Seed Certification Standard (Table 2). Other physical qualities *viz.* pure seed percentage, percent inert matter, mixing of other crop/weed seeds etc. are according to the seed quality standards. But most significantly, germination percentage was 22.93 (beans) to 55.67 (chilli) percent higher than the minimum required standard for foundation seeds, which indicated high quality of the organic seeds. Also none of the organically developed seeds failed the test for Seed borne diseases, which indicated the effectiveness of organic management towards quality seed development.

Comparative analysis of Seed Viability, Seed Vigor and Seed Resilience against Stress:

Germination percent (G%): Germination percent is the key indicator of seed quality and its viability towards field performance. Higher germination percent (89.0 to 94.6 percent) was observed in the case of organically developed seeds (mean germination 92.59 %) as compared to their conventional counterparts.

Seed Viability (SV %): Seed viability was tested through Tetrazolium test which showed value high score (ranged between 94.5 and 97.4) irrespective of the vegetable varieties indicating high quality of the organically developed seeds. At the same time organic seed showed on an average 3.03 % higher score than their conventional counterparts.

Germination Velocity Index (GVI): The length of time elapsed between the first seed to germinate and the last, the variation in germination speed and the timing that the majority of seeds germinate; all have impacts on diverse cultural operations like nutrient management, harvesting and field maturity of crops [Roberts 1981]. GVI value among the organic seeds under study was highest in case of french bean (25.72) followed by okra (21.49) and brinjal (15.53). Lower GVI value was noted in case of bottle gourd (9.54) and bittergourd (10.24) might be due to the hard seed coat that usually takes more time to germinate.

Seed Vigour (SV-I & SV-II): Seed vigour is the combination of characteristics that determine the potential for high performance after sowing. In fact, seed vigour is an interaction of characteristics that could be considered as independent attributes of physiological potential such as speed of germination, seedling growth and ability to germinate under abiotic stresses. Seed vigour test showed higher value (up to 23.98 %) in the case of organically developed vegetable seeds irrespective of seed varieties and irrespective of testing methodologies (SV-I & SV-II) as compared to conventional seeds. The values clearly indicated superiority of the organically developed seeds over the conventional ones.

Seed Resilience against Stress

Evaluation of seed resilience under abiotic stress was the most important component of this experimental protocol to assess the adoptability quality of the organically developed seeds in comparison to conventional seeds (Table 3). The study comprises four experimental protocol *viz.* Germination under water stress (G_{WS} %), Germination under salt stress (G_{SS} %), Germination under Accelerated ageing (G_{AA}%) and Electrical conductivity test to assess seed membrane integrity.

Germination in Water Stress (G_{WS} %): Germinating seeds in solutions of different water potentials is a convenient method for establishing the response of germination to low water potentials [Naylor, 1992]. Under water stress germination potentials of both type of the seeds reduced considerably, but more resilience was observed in the case of organically developed seeds which scored up to 14.29 % better performance than their conventional counterparts.

Germination in Salt Stress (G_{SS} %): Another major constraint to seed germination and seedling establishment is soil salinity, which is a limiting factor on crop production. Firstly, salinity reduces moisture availability by inducing osmotic stress and, secondly, creates nutrient imbalance and ionic toxicity [Munns and Tester, 2008]. Alike germination under water stress, germination potential under salt stress also reduced considerably, but here also, organically developed seeds showed better resilience (up to 13.2 % higher germination) in comparison to conventional seeds.

Germination under Accelerated Ageing (G_{AA}%) : The accelerated ageing test provides valuable information on storage and seedling field emergence potentials. Seeds are hydrated to a specific level when exposed to relatively high temperature (40 to 45^{o} C, usually 41^{o} C) and humidity (around 100 % Relative Humidity - RH). Under accelerated ageing, germination potential decreased in the cases of both the seeds, though the extent of reduction was not as documented under water stress and salt stress experiment. However, following the a trend similar to previous tests; the organically developed seeds showed superior performance (up to 10.74 % higher germination) in comparison to the conventional seeds.

Electrical Conductivity (EC): The principle of the EC test is that less vigorous or more deteriorated seeds show a lower speed of cell membrane repair during seed water uptake for germination and therefore release greater amounts of solutes to the external environment. The loss of leachate includes sugars, amino acids, fatty acids, proteins, enzymes, and inorganic ions (K^{+}, Ca^{+2}, Mg^{+2}, Na^{+}, Mn^{+2}) and the test evaluates the amount of ion leakage. The study sowed significantly higher value (up to 31.3 %) in the case of conventional seeds with respect to organically developed seeds which indicated that organic seeds are having more potential to fight against adverse field conditions.

CONCLUSION

The need to produce robust high vigour seeds that resist the negative impact of variable environmental conditions is the key component of climate change mitigation strategies. Quality seeds have higher energy reserve which gets efficiently translocated during germination and seedling establishment, and support photosynthesis-independent growth. Organic seed development program helped to infuse quality traits to the seeds in terms of high vigour and resilience towards abiotic stress. The intense plant health management helped to activate the plant physiological functioning, which in turn leads to quality, climate resilient seed production.

Table 1: Agronomic parameters of the vegetable plants 75 days post sowing (mean value)

Agronomic parameters	**Height of plants (cm)**	**Leaves / Plant**	**Branches / Plant**	**Flowers / plant**	**Fruits / Plant**
Fruit Vegetables					
Brinjal (Solanum melongena)	28.3	9.2	3.3	15.5	3.5
Chilli (Capsicum frutescensL.)	31.0	26.0	8.0	10.4	5.6
Okra (Abelmoschus esculentus)	31.5	12.5	5.4	4.0	3.8
Cherry Tomato (Solanum lycopersicum var. cerasiforme)	57.6	51.4	12.2	13.6	10.4
Cucurbits					
Bottle gourd (Lagenaria siceraria)	87.2	16.5	22.2	10.8	3.6
Bitter gourd (Momordica charantia L.)	86.5	23.5	11.8	6.2	2.2
Pumpkin (Cucurbita moschata (Duch.) Poir)	167.2	35.6	5.8	7.0	3.3
Green/Leafy Vegetables					
Red Amaranth (Amaranthus cruentus)	37.8	22.4	8.2	Seed formed	
Spinach (Spinacia oleracea)	36.9	19.6	5.6	Seed formed	
Others					
French Bean(Phaseolus vulgaris L)	23.4	32.2	13.4	7.3	4.8

Table 2: Indian Minimum Seed Certification Standard (2013) *vis- a- vis* Seeds produced at Nadia KVK (ICAR), under 'ORGANIC VEGETABLE SEED' Development Program.

Parameters	**Seed Standards**						**Specific Requirements***	
	Pure seed (min.) (%)	**Inert matter (max.) (%)**	**Other crop seeds (max.)**	**Weed seeds (max.)**	**Germination (min.) %**	**Moisture (max.) %**	**Off Type (%)**	**Seed borne diseases (%)**
Brinjal(Solanum melongena)								
Std. for Foundation Seeds	98.0	2.0	None	None	70.0	8.00	0.10	0.10
Organic seeds	99.4	0.6	None	None	94.6	7.65	None	None
Chilli (Capsicum frutescensL.)								
Std. for Foundation Seeds	98.0	2.0	5/kg	5 / kg	60.0	8.00	0.10	0.10
Organic seeds	99.8	0.2	None	None	93.4	7.40	None	None
Okra (Abelmoschus esculentus)								
Std. for Foundation Seeds	99.0	1.0	None	None	65.0	10.00	0.10	None
Organic seeds	99.8	0.2	None	None	94.0	8.82	None	None
Cherry Tomato (Solanum lycopersicum var. cerasiforme)								
Std. for Foundation Seeds	98.0	2.0	5/kg	None	70.0	8.00	0.10	0.10
Organic seeds	99.2	0.8	None	None	94.2	7.86	None	None
Bottle gourd (Lagenaria siceraria)								
Std. for Foundation Seeds	98.0	2.0	None	None	60.0	7.00	0.10	-
Organic seeds	99.7	0.3	None	None	92.4	6.50	None	None
Bitter gourd (Momordica charantia L.)								
Std. for Foundation Seeds	98.0	2.0	None	None	60.0	7.00	0.10	None
Organic seeds	99.7	0.3	None	None	92.3	5.94	None	None
Pumpkin (Cucurbita moschata (Duch.) Poir)								
Std. for Foundation Seeds	98.0	2.0	None	None	60.0	7.00	0.10	-
Organic seeds	99.8	0.2	None	None	87.2	6.24	None	None
Red Amaranth (Amaranthus cruentus)								

Std. for Foundation Seeds	95.0	5.0	5/kg	10/kg	70.0	8.00	0.10	0.01
Organic seeds	99.2	0.8	None	None	93.2	6.84	None	None
Spinach (Spinacia oleracea)								
Std. for Foundation Seeds	96.0	4.0	5/kg	5/kg	60.0	9.00	0.10	-
Organic seeds	98.6	1.4	None	None	90.4	8.22	None	None
French Bean (Phaseolus vulgaris L)								
Std. for Foundation Seeds	98.0	2.0	None	None	75.0	9.00	0.10	0.10
Organic seeds	99.6	0.4	None	None	92.2	8.69	None	None

*Maximum permitted at and after flowering

Table 3: Comparative study of Seed Viability, Seed Vigor and Seed Resilience Study at Nadia KVK(ICAR), under 'ORGANIC VEGETABLE SEED' Development Program.

Seed Quality parameters	Seed Viability		Seed Vigor			Seed Resilience against Stress			
	[1]G %	[2]SV %	[3]GVI	[4]SVI-I	[5]SVI- II	[6]G_{WS} %	[7]G_{SS} %	[8]G_{AA}%	[9]EC (dS/m)
Brinjal(Solanum melongena)									
[a]Conv. Seed	91.6	95.2	14.42	1205	248.7	68.5	64.2	78.4	0.023
[b]Org. Seed	94.6	97.4	15.53	1402	302.6	76.2	70.3	83.6	0.018
Chilli (Capsicum frutescensL.)									
[a]Conv. Seed	92.5	94.0	11.90	1494	302.5	70.4	67.2	76.3	0.105
[b]Org. Seed	93.4	97.2	12.96	1576	332.1	74.2	70.0	81.6	0.092
Okra (Abelmoschus esculentus)									
[a]Conv. Seed	91.2	94.0	18.90	1623	487.5	68.1	60.3	78.2	0.883
[b]Org. Seed	94.0	97.6	21.49	1853	524.0	70.5	65.1	80.2	0.609
Cherry Tomato (Solanum lycopersicum var. cerasiforme)									
[a]Conv. Seed	89.7	92.5	14.10	1770	489.6	65.4	62.2	74.5	0.091
[b]Org. Seed	94.2	96.0	15.68	1824	520.4	74.0	70.4	81.4	0.082
Bottle gourd (Lagenaria siceraria)									
[a]Conv. Seed	90.2	93.5	8.69	1322	321.4	63.2	60.5	75.2	0.078
[b]Org. Seed	92.4	95.0	9.54	1386	346.5	66.4	62.0	78.6	0.065
Bitter gourd (Momordica charantiaL.)									
[a]Conv. Seed	84.2	90.6	8.66	1475	391.2	62.3	60.5	73.6	0.120
[b]Org. Seed	92.3	94.5	10.24	1626	452.3	71.2	67.4	81.2	0.096
Pumpkin (Cucurbita moschata (Duch.) Poir)									
[a]Conv. Seed	91.4	94.5	14.58	1447	402.4	60.2	56.3	69.8	0.061
[b]Org. Seed	89.2	95.0	14.53	1602	498.9	64.4	60.2	76.5	0.056
Red Amaranth (Amaranthus cruentus)									
[a]Conv. Seed	89.0	93.2	12.13	1224	287.2	64.3	54.2	76.2	0.036
[b]Org. Seed	93.2	96.4	12.85	1304	324.5	67.9	58.6	80.0	0.029
Spinach (Spinacia oleracea)									
[a]Conv. Seed	87.2	94.3	12.26	1354	322.1	62.5	57.3	68.5	0.041
[b]Org. Seed	90.4	96.5	12.65	1406	364.5	64.0	60.5	74.6	0.035
French Bean (Phaseolus vulgaris L)									
[a]Conv. Seed	90.6	91.0	25.32	1465	283.2	60.4	57.2	75.4	0.021
[b]Org. Seed	92.2	95.5	25.72	1668	305.4	63.7	60.6	83.5	0.018

[a]Conv. Seed : Conventional seeds collected from recommended source; [b]Org. Seed : Organic seeds developed at Nadia KVK.

[1]G % : Germination percentage; [2]SV % : Seed Viability Study with Tetrazolium (TZ) assay test; [3]GVI : Germination Velocity Index; [4]SVI-I : Seed Vegor Index–I (Seedling length X Germination); [5]SVI-II : Seed VigourIindex –II (Seedling Dry Weight X Germination); [6]G_{WS} % : Germination under water stress (-1.2 MPa induced osmotic potential); [7]G_{SS} % : Germination under salt stress (-1.2 MPa induced osmotic potential); [8]G_{AA}% : Germination under accelerated ageing; [9]EC : Electrical conductivity.

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