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CONTENTS

RESEARCH/REVIEW PAPERS

1. Effect of Soil and Soilless Media on Agro Morphological, Yield and Economics of Lettuce (*Lactuca sativa* L.) Cultivars Under Protected Condition 1-7
Thushal R Y, Awani Kumar Singh, Gograj Singh Jat, Jeetendra Kumar Ranjan, Ram Asrey and Gyan Prakash Mishra
2. Assessments of Genetic Variability, Heritability and Genetic Advance in Tomato (*Lycopersicum esculentum*) 8-16
Sudhanshu Singh, Bijendra Singh, Satya Prakash, L.K.Gangwar, Vipin Kumar, R.S. Senger and Vikash Tyagi
3. Effect of Soil and Soilless Media on Biochemical Composition of Lettuce (*Lactuca sativa* L.) Cultivars Under Protected Condition 17-21
Thushal R.Y., Awani Kumar Singh, Gograj Singh Jat, Jeetendra Kumar Ranjan, Ram Asrey and Gyan Prakash Mishra
4. Characterization and Evaluation of Different Germplasm of Vegetable Mustards (Saag sarson) For North West Plain Zone of Uttar Pradesh 22-28
Arvind Kumar, Amit Kumar, Vipin Kumar, Satya Prakash, Mukesh Kumar, Dushyant Kumar Raghav and Shalini Singh
5. Effect of Different Colour Shade Nets on Germination and Seedling Growth of Papaya (*Carica papaya*) Var. GJP-1 29-36
Prof. Bhoomika Patel, Dr. P. D. Solanki, Prof. Sheetal Jadav, Prof. N. M. Patel, Dr. V. K. Parmar, Dr. Y. N. Tandel, Dr. C.S. Desai, Dr. D. R. Bhanderi and Dr. P. K. Parmar
6. Effect of integrated Nutrient Management on Growth of onion (*Allium cepa* L.) 37-46
Madan Pal and Joginder Singh
7. Integrated Impact of Inorganic and Bio-Fertilizers on Growth and Yield Attributes of Broad Bean (*Vicia faba* L.) Cv. Pusa Udit 47-51
Bhanu Pratap Singh, Anupam Tiwari, Joginder Singh, Ms Rathi, Abhay Vikram Singh, Saurabh Kumar Singh and Balram Yadav
8. Impact of Foliar Application of Plant Bio-Regulator and Micro-Nutrients on Fruit Retention, Yield and Quality Attributes of Aonla 52-59
Khushboo Arya, V.K. Tripathi and Manuj Awasthi

- 9. Response of Integrated Nutrient Management on The Economics of Broccoli (Brassica oleracea L. var. italica) Cv. Pusa KTS-1 60-63**
Krishan Choudhary, Jitendra Kumar, Pavitra Dev, Akshay Kumar and Shobhit Sharma
- 10. influence of Root Dipping Application As Starter Solution on Quality and Nutrient Uptake of Chilli (Capsicum annuum L.) 64-70**
Vikram Dutt, Gagandeep Singh, Manpreet Singh, Nirmal Singh
- 11. Study on Nutritional & Medicinal Properties of Lemon 71-76**
Satya Prakash, Dharmendra Kumar, Shubham Yadav and Bijendra Singh
- 12. Effect of Gibberellic Acid and Naphthalene Acetic acid on Initial Fruit Set, Drop, Retention, Yield and Quality of Ber (Ziziphus mauritiana Lamk.) 77-84**
Ankul Kumar, A.K. Singh, Manuj Awasthi, Somendra Verma and Shiwanand Pandey
- 13. Impact of Integrated Nutrient Management on Biochemical Parameters of Onion (*Allium cepa* L.) Cv. Pusa Red. 85-91**
Akshya Kumar*, Pavitra Dev, Jitendra Kumar, Shobhit Sharma and Krishan Choudhary



EFFECT OF SOIL AND SOILLESS MEDIA ON AGRO MORPHOLOGICAL, YIELD AND ECONOMICS OF LETTUCE (*LACTUCA SATIVA* L.) CULTIVARS UNDER PROTECTED CONDITION

**Thushal R. Y., Awani Kumar Singh*, Gograj Singh Jat,
Jeetendra Kumar Ranjan, Ram Asrey and Gyan Prakash Mishra**

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ABSTRACT

An investigation was conducted at CPCT, ICAR-Indian Agricultural Research Institute, New Delhi in 2022 to 23 to study the impact of soil and soilless media on lettuce cultivars. The study used a factorial randomized block design with 3 replications. Various agro morphological and yield parameters were analyzed for different lettuce genotypes. The results showed that lettuce grown in soil media had better outcomes, except for root length and weight, which were higher in soilless media. Among the varieties, V₉ (Lollo Rossa) performed well, while V₁₂ (Red Rose) performed poorly in leafy types. Concerning head types, V₁₆ (Great Lakes) performed well, while V₁₅ (Butterhead Green) performed poorly. Regarding economics, the cost of cultivation was consistent across all cultivars. However, V₉ (Lollo Rossa) had the highest gross income, net returns, and benefit-cost ratio for leafy types, while V₁₂ (Red Rose) had the lowest. Among the head types, V₁₆ (Great Lakes) had the highest gross income, net returns, and benefit-cost ratio, while V₁₅ (Butterhead Green) had the lowest. Soilless media resulted in higher cultivation expenses and lower gross income, net returns, and benefit-cost ratio than soil-based cultivation. In conclusion, Lettuce production has been determined to thrive best in soil, making it the most suitable medium for cultivation.

Keywords: *Soil, Soilless, Lettuce, Economics, Protected condition*

INTRODUCTION

Lettuce, a crucial salad crop, is an annual plant from the Asteraceae family with a chromosome number of 2n=18. It thrives in temperate regions and is native to the Mediterranean. Throughout history, Europe and North America held a strong position in the lettuce market; however, by the end of the 20th century, its appeal had expanded globally. In 2021, global production of lettuce

and chicory reached 27 MT, with 53% originating from China (Anonymous, 2023). In India, lettuce cultivation is concentrated in the northern regions, particularly in Jammu and Kashmir, Himachal Pradesh, and Uttarakhand.

Lettuce thrives in cool season conditions, necessitating humid weather, temperatures ranging from 10 to 20°C, and cool nights to ensure high-quality growth. Optimal growth conditions involve ample sunlight,

nitrogen-rich loose soil, and pH between 6.0 and 6.8. 1. Elevated temperatures may trigger lettuce bolting, particularly with most varieties experiencing difficulties above 24°C. Conversely, lower temperatures can enhance lettuce growth, with the optimal range being 16 to 18°C and tolerable conditions at 7°C. Partial shade can help to slow down the process of bolting in hot regions during the peak hours of the day. Germination of lettuce seeds is hindered by temperatures exceeding 27°C. The lifespan of lettuce varies from 65 to 130 days depending on the variety and planting season.

Lettuce is renowned for its positive impact on human health and nutrition. It is a rich source of dietary fibers, as well as essential minerals such as iron (1.24 mg/100 g), potassium (238 mg/100g), phosphorus (33 mg/100g), calcium (35 mg/100g), and manganese (0.179 mg/100g). Additionally, it offers a rich supply of vitamins including vitamin A (166 µg/100g), B1 (0.057 mg/100g), B6 (0.082 mg/100g), C (3.7 mg/100g), and K (102.3 µg/100g). Moreover, lettuce is an exceptional source of omega-3 fatty acids, which play a crucial role in promoting normal growth and development (Oh *et al.*, 2009). Consuming lettuce regularly in salads is recognized for its ability to help prevent osteoporosis, and iron deficiency (anemia), which protects against cardiovascular diseases, Age-related Macular Disease (ARMD) in elderly individuals, Alzheimer's disease, and various types of cancers. Additionally, lettuce comprises a range of other beneficial bioactive compounds like phenolics, ascorbic acid, tocopherol, and lignin, which possess significant medicinal properties, including anti-inflammatory, cholesterol-lowering, and anti-diabetic effects (Kim *et al.*, 2016).

Lettuce is a verdant vegetable cultivated in soil and soilless systems. Polyhouses serve as a protective barrier for crops, shielding them

from adverse conditions like excessive sunlight, extreme temperatures, rainfall, pests, and diseases. This not only helps in obtaining higher market prices but also ensures additional returns. The growing of vegetables in polyhouses underscores the significance of upholding an ideal plant density to boost production efficiency and enhance the quality of the harvest through the efficient utilization of space and nutrients.

The current study aimed to compare the impact of soil and soilless media in protected cultivation, considering the points mentioned above.

MATERIALS AND METHODS

The study was conducted at the Centre for Protected Cultivation and Technology (CPCT), ICAR- Indian Agricultural Research Institute, New Delhi, from November 2022 to March 2023. The region experiences a sub-tropical climate, with an average maximum temperature of 17.99° C and an average minimum temperature of 9.9° C. The annual rainfall averaged around 33.70 mm. In the current investigation, 16 genotypes were acquired from NBPGR and the private sector as the experimental material. The seeds were initially sown in 98-cell trays and subsequently transplanted to the main field after a month. The experiment was conducted using a Factorial Randomised Block design, with three replications. The plants were spaced at 50 cm × 20 cm intervals, with each plot measuring 2.0 m × 2.0 m. Various agro-morphological traits of lettuce cultivars grown in soil and soilless media under protected cultivation were studied. The agro-morphological characters studied were plant height (cm), plant canopy spread (cm), number of leaves, head and leafy type, head and leaf shape, heading firmness, leaf color, leaf length (cm), leaf width (cm), root length (cm), root weight (g), fresh plant biomass (g), and yield/m² (kg/m²).

The economic aspects of lettuce cultivation studied were the cost of cultivation (Rs/m²), gross income (Rs/m²), net returns (Rs/m²), and benefit-cost ratio.

In each replication, five plants were randomly chosen for each treatment and were then used to record observations on various component characters. The mean values of plant height, plant canopy spread, leaf length, leaf width, and root length were calculated and expressed in cm. Furthermore, the root weight and the fresh plant biomass were averaged and expressed in g.

Concerning economics, the Cost of Cultivation was determined by summing up all the overall expenses, including the cost of polyhouse and media cost in the case of soilless cultivation, specifically cocopeat.

Gross Income is described as the money earned before taxes and other deductions. It was calculated with the formula given below

Net Returns refer to the profit obtained after subtracting the expenses. This figure is determined by subtracting the gross income from the cultivation costs.

The benefit-cost ratio helps in comparing the benefits with those of costs. It is calculated as

Benefit-Cost Ratio = (Total Benefit)/(Total Cost)

The data was analyzed using R 3.4.1 software (InQuest Data Analytics, Bengaluru) and significance was determined by calculating F and P values, with values =0.05 considered significant.

RESULTS AND DISCUSSION

The morphological characters of lettuce genotypes like head or leaf type, head or leaf shape, head firmness, and leaf color are displayed in Table 1.

Lettuce genotypes were grouped into head or leaf types. Leafy varieties included Romaine I, Romaine II, Tango, Oak Leaf

Green, Grand Rapids, Harit Baigani, Oak Leaf Red, Red Romaine, Lolla Rossa, New Red Fire, Red Salad, and Red Rose. Head types included Iceberg Salista, Iceberg Crispiano, Butterhead Green, and Great Lakes.

Romaine I, Romaine II, Harit Baigani, and Oak Leaf Red had elongated leaves, while Oak Leaf Green had elongated rosette leaves. Tango had deeply lobed frilly leaves, Grand Rapids and New Red Fire had frilly leaves, Red Romaine had a spoon shape, Lolla Rossa had a rosette shape, and Red Salad and Red Rose had curly fan-shaped leaves. Iceberg Salista and Iceberg Crispiano had spherical leaves, Butterhead Green was round, and Great Lakes had globular leaves.

Some lettuce varieties like Romaine I, Romaine II, Tango, Oak Leaf Green, Grand Rapids, and Harit Baigani were green, while Oak Leaf Red, Red Romaine, Lolla Rossa, and New Red Fire were red. The Red salad was burgundy color, whereas Red Rose had a vibrant magenta color. Iceberg Salista, Iceberg Crispiano, Butterhead Green, and Great Lakes were all green.

Heading firmness confirms the compactness of heads. All leafy varieties had loose heads. Lolla Rossa, Iceberg Salista, and Iceberg Crispiano were tightly compact. Grand Rapids was loose and wavy whereas Oak Leaf Red was loose and serrated. Butterhead Green had a loose head whereas Great Lakes had solid head firmness.

All agro-morphological and yield characters performed better in soil except for root length and weight, as shown in tables 2 and 3. Compared to soilless media, the soil had higher values for plant height (29.22 cm), plant canopy spread (24.12 cm), number of leaves (26.91), leaf length (26.11 cm), leaf width (12.57 cm), fresh plant biomass (423.05 g), and yield (4.66 g). The increased plant height in the soil can be attributed to the availability of essential nutrients necessary for plant development, which is lacking in

soilless media (Anonymous, 2021). This trait of increased plant height also contributes to the plant canopy spread, number of leaves, leaf length, leaf width, fresh plant biomass, and yield. The current study's results on yield contradicted previous findings on lettuce by Majid *et al.* (2021), Gonnella *et al.* (2020), Michelon *et al.* (2020), Agius (2015), and Rouphael *et al.* (2004), who found higher yields in soilless media. Root length and weight were highest in lettuce genotypes grown in soilless

conditions, consistent with the findings of Lei and Engeseth (2021). However, root weight results aligned with the results of Nicola *et al.* (2004) on radish. Fresh plant biomass outcomes differed from Fontana and Nicola's (2009) results on corn salad and rocket. Gonnella *et al.* (2020) also found discrepancies in plant height results for lettuce.

Table 1 Morphological characters of Lettuce genotypes

Genotypes	Head or leaf type	Head or leaf shape	Color	Heading firmness
Romaine I (Long leaf)	Leafy	Elongated	Green	Loose
Romaine II (Small type)	Leafy	Elongated	Green	Loose
Tango	Leafy	Deeply lobed frilly	Green	Loose
Oak Leaf Green	Leafy	Elongated rosette	Green	Loose
Grand Rapids	Leafy	Frilly	Green	Loose, wavy
Harit Baigani	Leafy	Elongated	Green	Loose
Oak Leaf Red	Leafy	Elongated	Red	Loose, serrated
Red Romaine	Leafy	Spoon shape	Red	Loose
Lolla Rossa	Leafy	Rosette	Red	Tightly compact
New Red Fire	Leafy	Frilly	Red	Loose
Red Salad	Leafy	Curly, Fan shape	Burgundy	Loose
Red Rose	Leafy	Curly, Fan shape	Bright magenta	Loose
Iceberg Salista	Head	Spherical	Green	Tight
Iceberg Crispiano	Head	Spherical	Green	Tight
Butterhead Green	Head	Round	Green	Loose
Great Lakes	Head	Globose	Green	Solid

Among leafy-type varieties, Lollo Rossa exhibited the highest plant height (42.73 cm), plant canopy spread (25.69 cm), number of leaves (27.55), leaf length (31.32 cm), leaf width (13.92 cm), root length (14.47 cm), root weight (42.87 g), fresh plant biomass (552.73 g), and yield (5.71 kg/m²). On the other hand, Red Rose had the lowest plant height (22.70 cm), plant canopy spread (20.06 cm), number of leaves (14.72), leaf length (17.33 cm), leaf width (7.76 cm), root length (6.58 cm), root weight (29.07 g), fresh plant biomass (216.97

g), and yield (2.25 kg/m²). For head-type varieties, Great Lakes recorded the highest plant height (33.11 cm), plant canopy spread (28.79 cm), number of leaves (40.72), leaf length (39.86 cm), leaf width (17.51 cm), root length (12.33 cm), root weight (49.59 g), fresh plant biomass (680.79 g), and yield (6.99 kg/m²). Conversely, Butterhead Green had the lowest plant height (23.67 cm), plant canopy spread (24.26 cm), number of leaves (28.21), leaf length (15.75 cm), leaf width (13.17 cm), root length (6.90 cm), root weight (33.57 g),

fresh plant biomass (339.72 g), and yield (3.58 kg/m²).

The economics of lettuce production analyzed are presented in Table 4. Lettuce genotypes grown in soil had higher gross income, net returns, and benefit-cost ratios than those grown in soilless media. The cost of cultivation was higher for lettuce genotypes grown in soilless media and showed an inverse relationship with gross income, net returns, and benefit-cost ratio. The cost of cultivation was consistent for all varieties, 225 Rs/m² for soil and 325 Rs/m² for soilless. Lollo Rossa had the highest gross income (371.15 Rs/m²), net returns (96.15 Rs/m²), and benefit-cost ratio (1.42:1) whereas Red Rose had the lowest

gross income (146.25 Rs/m²), net returns (-128.75 Rs/m²), and benefit-cost ratio (0.57:1) among the leafy types. Great Lakes had the highest gross income (454.35 Rs/m²), net returns (179.35 Rs/m²), and benefit-cost ratio (1.73:1) whereas Butterhead Green had the lowest gross income (232.70 Rs/m²), net returns (-42.30 Rs/m²), and benefit-cost ratio (0.90:1) among the head types.

According to the aforementioned research, soil serves as the optimal substrate for cultivating lettuce in protected environments, resulting in higher profits, as soilless media contains fewer nutrients than soil. Among leafy lettuce varieties, Lollo Rossa and Great Lakes are the recommended choices for

cultivation under protected conditions among leafy head lettuce varieties.

Table 2 Effect of growing media on agro-morphological traits of lettuce genotypes

Treatments	Plant height (cm)			Plant canopy spread (cm)			Number of leaves			Leaf length (cm)			Leaf width (cm)		
	M ₁	M ₂	Mean	M ₁	M ₂	Mean	M ₁	M ₂	Mean	M ₁	M ₂	Mean	M ₁	M ₂	Mean
V ₁ – Romaine I	29.22	26.35	27.79	21.82	19.57	20.70	23.07	19.03	21.05	21.17	18.42	19.80	10.13	8.47	9.30
V ₂ – Romaine II	40.14	37.27	38.71	25.38	23.13	24.26	28.24	24.20	26.22	31.94	29.19	30.57	13.53	11.87	12.70
V ₃ – Tango	38.81	35.94	37.38	24.11	21.86	22.99	26.62	22.58	24.60	28.23	25.48	26.86	13.42	11.76	12.59
V ₄ – Oak Leaf Green	38.55	35.68	37.12	23.52	21.27	22.40	25.95	21.91	23.93	28.08	25.33	26.71	13.00	11.34	12.17
V ₅ – Grand Rapids	35.14	32.27	33.71	23.15	20.90	22.03	25.74	21.70	23.72	27.99	25.24	26.62	11.75	10.09	10.92
V ₆ – Harit Baigani	34.57	31.70	33.14	22.49	20.24	21.37	23.24	19.20	21.22	23.56	20.81	22.19	10.50	8.84	9.67
V ₇ – Oak Leaf Red	34.34	31.47	32.91	22.14	19.89	21.02	24.52	20.48	22.50	23.94	21.19	22.57	11.59	9.93	10.76
V ₈ – Red Romaine	33.64	30.77	32.21	21.95	19.70	20.83	23.23	19.19	21.21	21.68	18.93	20.31	10.22	8.56	9.39
V ₉ – Lollo Rossa	44.16	41.29	42.73	26.81	24.56	25.69	29.57	25.53	27.55	32.69	29.94	31.32	14.75	13.09	13.92
V ₁₀ – New Red Fire	24.77	21.90	23.34	21.43	19.18	20.31	22.67	18.63	20.65	20.62	17.87	19.25	9.17	7.51	8.34
V ₁₁ – Red Salad	24.40	21.53	22.97	21.27	19.02	20.15	19.90	15.86	17.88	19.89	17.14	18.52	8.75	7.09	7.92
V ₁₂ – Red Rose	24.13	21.26	22.70	21.18	18.93	20.06	16.74	12.70	14.72	18.70	15.95	17.33	8.59	6.93	7.76
V ₁₃ – Iceberg Salista	29.02	26.15	27.59	28.10	25.85	26.98	34.90	30.86	32.88	38.14	35.39	36.77	17.83	16.17	17.00
V ₁₄ – Iceberg Crispiano	26.39	23.52	24.96	27.32	25.07	26.20	33.24	29.20	31.22	22.62	19.87	21.25	15.59	13.93	14.76
V ₁₅ – Butterhead Green	25.10	22.23	23.67	25.38	23.13	24.26	30.23	26.19	28.21	17.12	14.37	15.75	14.00	12.34	13.17
V ₁₆ – Great Lakes	34.54	31.67	33.11	29.91	27.66	28.79	42.74	38.70	40.72	41.23	38.48	39.86	18.34	16.68	17.51
Mean	29.22	26.35	27.79	24.12	21.87	22.99	26.91	22.87	24.89	26.11	23.36	24.74	12.57	10.91	11.74

M₁ – Soil M₂ – Soilless

Table 3 Effect of growing media on yield traits of lettuce genotypes

Treatments	Root length (cm)			Root weight (cm)			Fresh plant biomass (g)			Yield (kg/m ²)		
	M ₁	M ₂	Mean	M ₁	M ₂	Mean	M ₁	M ₂	Mean	M ₁	M ₂	Mean
V ₁ – Romaine I	6.48	7.23	6.86	29.78	31.16	30.47	313.67	260.32	286.99	3.53	2.57	3.05
V ₂ – Romaine II	12.55	13.30	12.93	41.86	43.24	42.55	434.25	381.34	407.80	4.90	3.94	4.42
V ₃ – Tango	10.04	10.79	10.42	39.18	40.56	39.87	419.27	366.08	392.68	4.69	3.73	4.21
V ₄ – Oak Leaf Green	8.15	8.90	8.53	38.26	39.64	38.95	408.13	355.14	381.64	4.78	3.82	4.30
V ₅ – Grand Rapids	7.19	7.94	7.57	34.05	35.43	34.74	401.42	348.12	374.77	4.41	3.45	3.93
V ₆ – Harit Baigani	6.63	7.38	7.01	31.38	32.76	32.07	369.56	316.13	342.85	4.09	3.13	3.61
V ₇ – Oak Leaf Red	6.80	7.55	7.18	31.99	33.37	32.68	389.17	336.15	362.66	4.39	3.43	3.91
V ₈ – Red Romaine	6.59	7.34	6.97	30.37	31.75	31.06	347.84	294.12	320.98	3.87	2.91	3.39
V ₉ – Lollo Rossa	14.09	14.84	14.47	42.18	43.56	42.87	579.32	526.13	552.73	6.19	5.23	5.71
V ₁₀ – New Red Fire	6.45	7.20	6.83	28.97	30.35	29.66	314.56	261.32	287.94	3.50	2.54	3.02
V ₁₁ – Red Salad	6.30	7.05	6.68	28.55	29.93	29.24	244.52	191.32	217.92	2.90	1.94	2.42
V ₁₂ – Red Rose	6.20	6.95	6.58	28.38	29.76	29.07	243.62	190.32	216.97	2.73	1.77	2.25
V ₁₃ – Iceberg Salista	7.92	8.67	8.30	43.17	44.55	43.86	654.45	601.08	627.77	6.94	5.98	6.46
V ₁₄ – Iceberg Crispiano	7.58	8.33	7.96	41.15	42.53	41.84	575.28	522.21	548.75	6.15	5.19	5.67
V ₁₅ – Butterhead Green	6.52	7.27	6.90	32.88	34.26	33.57	366.32	313.12	339.72	4.06	3.10	3.58
V ₁₆ – Great Lakes	11.95	12.7	12.33	48.90	50.28	49.59	707.34	654.23	680.79	7.47	6.51	6.99
Mean	8.22	8.97	8.59	35.69	37.07	36.38	423.05	369.82	396.43	4.66	3.70	4.18

M₁ – Soil M₂ – Soilless**Table 4 Effect of different growing media on the economics of lettuce genotypes**

Treatments	Cost of Cultivation (Rs/m ²)			Gross Income (Rs/m ²)			Net Returns (Rs/m ²)			Benefit-Cost Ratio		
	M ₁	M ₂	Mean	M ₁	M ₂	Mean	M ₁	M ₂	Mean	M ₁	M ₂	Mean
V ₁ – Romaine I	225.00	325.00	275	229.45	167.05	198.25	4.45	-157.95	-76.75	1.02	0.51	0.77
V ₂ – Romaine II	225.00	325.00	275	318.50	256.10	287.30	93.50	-68.90	12.30	1.42	0.79	1.10
V ₃ – Tango	225.00	325.00	275	304.85	242.45	273.65	79.85	-82.55	-1.35	1.35	0.75	1.05
V ₄ –Oak Leaf Green	225.00	325.00	275	310.70	248.30	279.50	85.70	-76.70	4.50	1.38	0.76	1.07
V ₅ –Grand Rapids	225.00	325.00	275	286.65	224.25	255.45	61.65	-100.75	-19.55	1.27	0.69	0.98
V ₆ –Harit Baigani	225.00	325.00	275	265.85	203.45	234.65	40.85	-121.55	-40.35	1.18	0.63	0.90
V ₇ –Oak Leaf Red	225.00	325.00	275	285.35	222.95	254.15	60.35	-102.05	-20.85	1.27	0.69	0.98
V ₈ – Red Romaine	225.00	325.00	275	251.55	189.15	220.35	26.55	-135.85	-54.65	1.12	0.58	0.85
V ₉ – Lollo Rossa	225.00	325.00	275	402.35	339.95	371.15	177.35	14.95	96.15	1.79	1.05	1.42
V ₁₀ –New Red Fire	225.00	325.00	275	227.50	165.10	196.30	2.50	-159.90	-78.70	1.01	0.51	0.76
V ₁₁ – Red Salad	225.00	325.00	275	188.50	126.10	157.30	-36.50	-198.90	-117.70	0.84	0.39	0.61
V ₁₂ – Red Rose	225.00	325.00	275	177.45	115.05	146.25	-47.55	-209.95	-128.75	0.79	0.35	0.57
V ₁₃ –Iceberg Salista	225.00	325.00	275	451.10	388.70	419.90	226.10	63.70	144.90	2.00	1.20	1.60
V ₁₄ – Iceberg Crispiano	225.00	325.00	275	399.75	337.35	368.55	174.75	12.35	93.55	1.78	1.04	1.41
V ₁₅ – Butterhead Green	225.00	325.00	275	263.90	201.50	232.70	38.90	-123.50	-42.30	1.17	0.62	0.90
V ₁₆ – Great Lakes	225.00	325.00	275	485.55	423.15	454.35	260.55	98.15	179.35	2.16	1.30	1.73
Mean	225.00	325.00	275	303.06	240.66	271.86	78.06	-84.34	-3.14	1.35	0.74	1.04

M₁ – Soil M₂ – Soilless

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REFERENCES

1. Agius C. 2015. The yield and quality of lettuce crop grown in different growing media. *Doctoral dissertation*, University of Malta.
2. Anonymous. 2021. Gardening without soil-cocopeat to grow healthy plants for bountiful yields. Sai International Trading Company.
3. Anonymous. 2023. Lettuce (with chicory) production in 2021; Countries/ Regions/ Production Quantity from pick lists. UN Food & Agriculture Organization, Statistics Division (FAOSTAT).
4. Fontana E and Nicola S. 2009. Traditional and soilless culture systems to produce corn salad (*Valerianella olitoria* L.) and rocket (*Eruca sativa* Mill.) with low nitrate content. *Journal of Food Agriculture and Environment* **7**(2); 405-10.
5. Gonnella M, Renna M and Serio F. 2020. Yield and quality of greenhouse multi-leaf lettuce cultivars grown in soil and soilless culture under Mediterranean conditions. *Italus Hortus* **27**, 18-30.
6. Kim M J, Moon Y, Tou J, Mou B and Waterland N. 2016. Nutritional value, bioactive compounds and health benefits of lettuce (*Lactuca sativa* L.): study review. *Journal of Food Composition and Analysis* **49**, 19-34.
7. Lei C and Engeseth N J. 2021. Comparison of growth characteristics, functional qualities, and texture of hydroponically grown and soil-grown lettuce. *LWT*. **150**.
8. Majid M, Khan J N, Shah Q M A, Masoodi K Z, Afroza B and Parvaze S. 2021. Evaluation of hydroponic systems for the cultivation of Lettuce (*Lactuca sativa* L., var. *longifolia*) and comparison with protected soil-based cultivation. *Agricultural Water Management* **245**.
9. Michelon N, Pennisi G, Myint N O, Dall'Olio G, Batista L P, Salviano A A C and Gianquinto G. 2020. Strategies for improved yield and water use efficiency of lettuce (*Lactuca sativa* L.) through simplified soilless cultivation under semi-arid climate. *Agronomy* **10**(9); 1379.
10. Nicola S, Fontana E, Hoeberechts J and Saglietti D. 2004. Raphanus sativus production in soilless or traditional culture systems and postharvest packaging. In *V International Postharvest Symposium* **682**; 1303-10.
11. Oh M M, Trick H N. and Rajashekar C B. 2009. Secondary metabolism and antioxidants are involved in environmental adaptation and stress tolerance in lettuce. *Journal of Plant Physiology*, **166**(2); 180-91.
12. Rouphael Y, Colla G, Battistelli A, Moscatello S, Proietti S and Rea E. 2004. Yield, water requirement, nutrient uptake and fruit quality of zucchini squash grown in soil and closed soilless culture. *Journal of Horticultural Science and Biotechnology* **79**; 423-30.



ASSESSMENTS OF GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE IN TOMATO (*LYCOPERSICON ESCULENTUM*)

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ABSTRACT

The study focused on evaluating 48 different tomato genotypes for 13 morphological traits to estimate the genetic variability, heritability and genetic advance at the Horticulture Research Centre of Sardar Vallabhbhai Patel University of Agriculture and Technology in Meerut, following randomized complete block design with three replications during two consecutive Rabi seasons (October 2022 and April 2024). The results of analysis of variance revealed that for all quantitative features included for both the season, analysis of variance indicated highly significant variations among genotypes. The phenotypic and genotypic coefficient of variation ranged from 4.92% to 16.42% and 4.23% to 12.93% respectively. Higher PCV compared to GCV observed for all traits revealed that the influence of environment on traits. High heritability estimates obtained for day to first fruit set, days to first fruit maturity, plant height, days to first fruit harvesting, days taken germination, number of fruits per plant, fruit yield (t/ha), fruit length, fruit yield (kg/plant), fruit yield (kg/plot), High Genetic Advance for number of primary branch, plant height, fruit length, days to first fruit set. High heritability coupled with High Genetic Advance Observed for day to first fruit set, plant height, days to first fruit set, fruit length. As yield is the most important dependent trait, day to first fruit set, plant height, days to first fruit set, fruit length can be selected as selection parameters for further crop improvement programs.

Keywords: Tomato, genetic variability, heritability and Genetic Advance

INTRODUCTION

Tomato belongs to Solanaceae family along with other economically important crops such as pepper, eggplant and potato. It is a significant vegetable crop of special economic importance in the horticultural industry worldwide. Tomato possesses unique properties due to its diploid, fairly compact and recently sequenced genome with the genome size of 950 mb (Mega base pair). The C.M. Rick Tomato Genetics Resource Center (TGRC) at the University of California, Davis maintains seed stocks of accessions of wild relatives, monogenic mutants, and miscellaneous genetic stocks of tomato. Tomato is the most important warm season fruit vegetable grown throughout the world. Tomatoes are consumed as fresh and in processed form. Tomato as a fresh vegetable used in several dishes, sandwiches, salad, etc. and can be processed into several forms like paste, puree, syrup, juice, ketchup, sauce, whole peeled tomato etc. Tomato is universally treated as the important 'Protective Food' because of its special nutritive value viz., it is rich source of minerals, vitamins, organic acids and regular consumption of tomatoes and tomato based products has been associated with a reduced risk of (Giovannucci et al., 1999). Tomatoes are an excellent source of vitamin C, which is important for immune function, collagen synthesis, and antioxidant protection. Vitamin C content in tomatoes can vary based on the variety and ripeness. According to (Aykroyd, 1966) tomato fruit contain 93.1 g water, protein 19 g, fat 0.1 g, carbohydrate 3.6 g, mineral matter 0.6 g, calcium 20 mg, phosphorous 36 mg, iron 0.8 mg, carotene (as vitamin A) 320 I U, thiamine 2.27 mg, nicotinic acid 0.4 mg, riboflavin 0.01 mg and ascorbic acid 31 mg per 100 g of pulp of fruit. It also contains folic acid, vitamin K and inhibitors which are related to vitamin E. The tomato growth characteristics range from

indeterminate to highly determinate type; indeterminate plant keeps growing and produces fruits until frost kills the plant. However, well-drained, sandy or red loam soils rich in organic matter with a pH range of 6.0-7.0 are considered as ideal. Tomato is a warm season crop. The best fruit colour and quality is obtained at a temperature range of 21- 24°C. Tomato is a warm-season crop that exhibits two types of plant growth habits: determinate and indeterminate. Tomato is one of the most important vegetables in India accounting for about 11.04 percent of the total vegetables production in the country. It is one of the most important "protective foods" because of its special nutritive value. But, due to its high perishability it cannot be preserved in fresh form throughout the year. Leading producers of tomato in the World are China (67.63 million tonnes), accounting for 26% of the total production, followed by India (21.18 million tonnes), Turkey (13.09 million tonnes), USA (10.47 million tonnes), Italy (6.64 million tonnes), Egypt (6.24 million tonnes) and Spain (4.75 million tonnes) (NHB 2023 - 24).

MATERIAL AND METHODS

The present experiment was conducted during the Rabi season of the year 2022-2023 and 2023-2024 at Horticulture Research Centre, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, in three replication using 48 tomato genotypes.

The data or observations were taken based on 5 randomly selected plants from each replication for 13 traits viz; day taken to germination, plant height(cm), the number of primary branches, fruit length(cm), days to 50% flowering, days to first fruit set, days to first fruit maturity, days to first fruit harvesting, the number of fruits per plant, five fruit weight(g), fruit yield(kg/ plant), fruit yield per plot (kg/plot) and fruit yield per ha(tonne/ha).

Statistical Analysis

Analysis of variance (ANOVA) will be done as outlined by Panse and Sukhatme(1967). The coefficient of variations heritability in broad sense and expected genetic advance were estimated, as suggested by Burtan, 1952, Hanson et al., 1956 and Johnson et al., 1956 respectively. Heritability is defined as the measure of correspondence between breeding values and phenotypic values. It is worked out by using the formula suggested by Lush (1949) and Burton and Devance (1953) and expressed in percentage according to Weber and Moorty (1952). The expected genetic advance under selection for the difference characters will be estimated as suggested by Allard (1960).

RESULTS AND DISCUSSION

Analysis of variance

The analysis of variance was carried out for all 48 genotypes for 13 traits . The mean square of different genotypes for all the studied characters of rabi 2022-2023, 2023-2024 and pooled is presented in Table 1a, 1b and 1c. The significant value for all the characters revealed that the result of different genotypes of tomato showed the sufficient variability in both season (2022-2023 and 2023-2024) as well as in pooled analysis both season and give ample scope for the selection viz., day taken to germination, days to 50% flowering, days to first fruit set, days to first fruit maturity, days to fruit harvesting, plant height (cm), number of primary branches, fruit length (cm), number of fruit per plant, five fruit weight (g), fruit yield (g/plant), fruit yield (g/plot), fruit yield (t/ha). Similar observation were also recorded by : Anuradha et al., (2020) and Prajapati et al., (2015)

Parameters of Genetic Variability

Genetic variability is one of the most

important requirements for an effective breeding programme. The amount of variation present in a genetic stock may be estimated using the phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV), which can then be used to develop an efficient breeding programme. For each character, PCV and GCV estimations were calculated. In a general sense, heritability is a crucial indicator for breeders since it reveals the reliability with which a genotype may be recognised from its phenotypic manifestation. Heritability and genetic progress work better together to assess the genuine effects of selection. The estimates of genetic parameters, such as The Phenotypic Coefficient of Variation , Genotypic Coefficient of Variation , heritability in the broad sense and Genetic Advance as percentage of mean for various characteristics, are shown in Tables 2a, 2b, and 2c.

Phenotypic Coefficient of Variation

Rabi Season (2022-2023): The phenotypic coefficient of variation ranged from 7.16 to 25.63% and high phenotypic coefficient of variation existed for number of primary branch (25.63%), Moderate PCV was observed for fruit length (cm) (18.71%), days taken germination (14.59%), days to first fruit set (13.14%), plant height (cm) (12.41%), fruit yield (kg/plot) (12.28%), number of fruits per plant (11.77%), fruit yield(t/ha) (10.95%), days to first fruit maturity (10.30%), fruit yield (kg/plant) (10.15%) and Low PCV was observed for days to first fruit harvesting (9.88 %), five fruit weight(g) (8.52%), days to 50% flowering (7.61%).

Rabi Season (2023-2024): The phenotypic coefficient of variation ranged from 6.20% to 21.17% and high phenotypic coefficient of variation existed for number of primary branch (21.17%), Moderate PCV was observed for fruit length (cm) (17.20%), days to

first fruit set (12.69%), plant height (cm) (12.50%), days taken germination (11.26%), fruit yield (kg/plant) (11.07%), fruit yield(kg/plot) (10.00%) and Low PCV was observed for number of fruits per plant (9.15%), fruit yield(t/ha) (8.58%), five fruit weight(g) (6.99%), days to first fruit maturity (6.65%), days to first fruit harvesting (6.65 %), days to 50%flowering (6.20%).

Pooled Rabi Season (2022-2023 and 2023-2024): The phenotypic coefficient of variation ranged from 4.92% to 16.42% and Moderate PCV was observed for number of primary branch (16.42%), fruit length (cm) (13.03%), days to first fruit set (12.66%), plant height (cm) (11.68%), days taken germination (10.63%) and Low PCV was observed for fruit yield (kg/plot) (9.25%), number of fruits per plant (9.00%), fruit yield (kg/plant) (8.56%), fruit yield(t/ha) (8.42%), days to first fruit maturity (7.42%), days to first fruit harvesting (7.11%), five fruit weight(g) (6.30%), days to 50%flowering (4.92%).

Genotypic Coefficient of Variation

Several genetic variables were studied because PCV alone does not reveal the proportional amount of variance. Rabi Season (2022-2023): The genotypic coefficient of variation ranged from 6.97% to 22.04% and high genotypic coefficient of variation existed for number of primary branch (22.04%), Moderate GCV was observed for fruit length (cm) (17.40%), days taken germination (13.30%), days to first fruit set (12.68%), plant height (cm) (11.43%), number of fruits per plant (11.23%), fruit yield (kg/plot) (10.93%) and Low GCV was observed for days to first fruit maturity (9.58%), fruit yield(t/ha) (9.40%), days to first fruit harvesting (9.22%), fruit yield (kg/plant) (9.17%), five fruit weight(g) (7.18%), days to 50%flowering (6.97%).

Rabi Season (2023-2024): The genotypic

coefficient of variation ranged from 4.54% to 15.59% and Moderate GCV was observed for number of primary branch (15.59%), fruit length (cm) (15.31%), days to first fruit set (12.42%), plant height (cm) (11.90 %), days taken germination (10.08%), Low GCV was observed for fruit yield (kg/plant) (9.42%), fruit yield (kg/plot) (8.63%), fruit yield(t/ha) (7.91%), number of fruits per plant (7.71%), days to first fruit maturity (6.59 %), days to first fruit harvesting (6.24%), five fruit weight(g) (5.27%), days to 50%flowering (4.54%).

Pooled Rabi Season (2022-2023 and 2023-2024): The genotypic coefficient of variation ranged from 4.23% to 12.93% and Moderate GCV was observed for number of primary branch (12.93%), days to first fruit set (12.49%), fruit length (cm) (12.06%), plant height (cm) (11.17 %), %, days taken germination (10.06%) and Low GCV was observed for number of fruits per plant (8.42%), fruit yield (kg/plot) (8.29%), fruit yield(t/ha) (7.84%), fruit yield (kg/plant) (7.74%), days to first fruit maturity (7.11%), days to first fruit harvesting (6.79%), five fruit weight(g) (5.59%), days to 50%flowering (4.23%). This result for both PCV and GCV was consistent with several prior publications by Kale et al. (1988), Reddy and Reddy (1992), Indu Nair and Thamburaj (1995), Mohanty (2002b), Ara et al. (2009), Meena and Bahadur (2014) and Ahmad et al.(2016), Kale et al. (1988), Reddy and Reddy (1992), Indu Nair and Thamburaj (1995), Mohanty (2002a), Ara et al. (2009), Meena and Bahadur(2014) and Ahmad et al. (2016).

Heritability

Breeders consider heritability, in a broad sense, to be an important statistic since its quantity demonstrates the reliability with which a genotype may be determined from the expression of its phenotype (Lush 1940). For most of the characteristics throughout the

Rabi season 2022-2023 and Rabi season 2023-2024 of the current study, high heritability estimates and moderate to high estimates, respectively, were found.

Rabi Season (2022-2023): Heritability in broad sense (h^2_{bs}) ranged from 73.60% to 91.18% (Table 4.3a) and all traits showed high heritability. High heritability estimates obtained for days to first fruit set (93.18%), number of fruits per plant (91.07%), days to first fruit harvesting (87.16%), fruit length (cm) (86.45%), days to first fruit maturity (86.44%), plant height (cm) (84.84%), five fruit weight(g) (84.01%), days to 50%flowering (83.90%) days taken germination (83.03%) fruit yield (kg/plant) (81.59%), fruit yield (kg/plot) (79.25%), number of primary branch (73.98%), fruit yield(t/ha) (73.60%).

Rabi Season (2023-2024): Heritability in broad sense (h^2_{bs}) ranged from 53.69% to 95.82% and all traits showed the high heritability. High heritability estimates obtained for days to first fruit set (95.82%), plant height (cm) (90.63%), days to first fruit maturity (89.38%), days to first fruit harvesting (87.94%), fruit yield(t/ha) (84.91%), days taken germination (80.10%), fruit length (cm) (79.23%), fruit yield (kg/plot) (74.46%), fruit yield (kg/plant) (72.46%), number of fruits per plant (71.12%), five fruit weight(g) (56.80%), number of primary branch (54.24%), days to 50%flowering (53.69%).

Pooled Rabi Season (2022-2023 and 2022-2023): Heritability in broad sense (h^2_{bs}) ranged from 90.67 to 99.95% and all traits showed the high heritability. High heritability estimates obtained for first fruit set (97.28%), days to first fruit maturity (91.92%), plant height (cm) (91.41%), days to first fruit harvesting (91.25%), days taken germination (89.51%), number of fruits per plant (87.59%), fruit yield (t/ha) (86.65%), fruit length (cm) (85.64%), fruit yield (kg/plant) (81.59%), fruit yield (kg/plot) (80.26%), five fruit weight(g) (78.91%), days to 50%flowering (73.85%),

number of primary branch (62.01%)

The high heritability of the characteristics imply that selection based on phenotypic performance is reliable since variation is more genetically determined and less influenced by external factors. High heritability values also imply that the phenotypes are being influenced by genes operating in an additive manner. The selection of these features in a future breeding programme makes sense. Heritability levels alone might not be adequate to determine breeding value. The eventual effects of selection may be predicted more accurately and effectively when heritability and genetic advancement are combined. This result was consistent with several prior publications by Bora et al. (1993), Pujari et al. (1995), Mittal et al. (1996), Reddy et al. (2013), Sherpa et al. (2014) and Ahmad et al. (2016).

Genetic Advance (%Mean)

To select for a trait, one often looks for its phenotypic expression, which is the result of the interaction between the environment and the genotype. Hence, phenotypic superiority of plants above the original population is a result of both genotypes and favorable environmental variables. In such a case, genetic advancement provides a reliable predictor of real advances to be made in the research group. Johnson et al. (1955) emphasized that the interaction of genetic development and heredity is more crucial than heritability alone for determining the true effects of selection.

Rabi Season (2022-2023): The range of genetic gain varied from 13.15% to 39.05%(Table 4.3a). The moderate Genetic Advance as percent mean was exhibited by for days to 50% flowering (13.15%), five fruit weight(g) (14.75%), fruit yield(t/ha) (16.61%), fruit yield (kg/plant) (17.07%), days to first fruit harvesting (17.74%), days to first fruit maturity (18.35%) and rest of the characters

showed the high Genetic Advance for fruit yield (kg/plot) (20.05%), plant height (cm) (21.68%), number of fruits per plant (22.08%), days taken germination (24.96%), days to first fruit set (25.22%), fruit length (cm) (33.32%), number of primary branch (39.05%).

Rabi Season (2023-2024): The range of genetic advance varied from 6.86% to 28.08%. The low Genetic Advance as percent mean was exhibited by days to 50% flowering (6.86%), five fruit weight(g) (8.18%), Moderate Genetic Advance as percent mean was exhibited days to first fruit harvesting (12.05%), days to first fruit maturity (12.83%), number of fruits per plant (13.40%), fruit yield(t/ha) (15.01%), fruit yield (kg/plot) (15.34%), fruit yield (kg/plant) (16.35%), days taken germination (18.58%) and rest of the characters showed the high Genetic Advance for plant height (cm) (23.35%), number of primary branch (23.66%), days to first fruit set (25.04%), fruit length (cm) (28.08%).

Pooled Rabi Season (2022-2023 and 2023-2024): The range of genetic gain varied from 7.49% to 25.37%. The low Genetic Advance as percent mean was exhibited by days to 50% flowering (7.49%), Moderate Genetic Advance as percent mean was exhibited five fruit weight(g) (10.24%), days to first fruit harvesting (13.36%), days to first fruit maturity (14.05%), fruit yield (kg/plant) (14.39%), fruit yield (t/ha) (15.03%), fruit yield (kg/plot) (15.29%), number of fruits per plant (16.24%), days taken germination (19.90%) and rest of the characters showed the high Genetic Advance for number of primary branch (20.98%), plant height (cm) (22.00%), fruit length (cm) (22.98%), days to first fruit set (25.37%). This result was consistent with several prior publications by Reddy et al. (2013), Sherpa et al. (2014), Meena and Bahadur (2014) and Ahmad et al. (2016).

Table 1a Analysis of variance in 48 Tomato Genotypes for Rabi season 2022-2023

Source of variation	DF	Day taken to Germination	Days to 50% Flowering	Days to first fruit set	Days to first fruit maturity	Days to first fruit harvesting	Plant Height (cm)	Number of Primary Branches	Fruit Length (cm)	Number of fruits per plant	Five Fruit weight (g)	Fruit yield (kg/plant)	Fruit Yield (kg / plot)	Fruit Yield (t/ ha)
Rep.	2	0.14	3.82	6.39	2.40	0.77	8.40	0.58	0.39	12.52	849.78	0.006	0.025	0.018
Treat	47	8.17**	80.92*	105.54**	82.43*	80.21*	358.49**	3.94**	2.13**	173.96**	1480.87**	0.044*	0.610*	2.914*
Error	94	0.52	4.87	2.51	4.10	3.76	20.15	0.41	0.11	5.51	88.32	0.003	0.049	0.311
Total	143	3.03	29.85	36.43	29.82	28.84	131.19	1.57	0.78	60.97	556.66	0.017	0.233	1.163

Table 1b Analysis of variance in 48 Tomato Genotypes for Rabi season 2023-2024

Source of variation	DF	Day taken to Germination	Days to 50% Flowering	Days to first fruit set	Days to first fruit maturity	Days to first fruit harvesting	Plant Height (cm)	Number of Primary Branches	Fruit Length (cm)	Number of fruits per plant	Five Fruit weight (g)	Fruit yield (kg/plant)	Fruit Yield (kg / plot)	Fruit Yield (t/ ha)
Rep.	2	1.20	4.66	2.25	0.92	0.05	0.41	1.80	0.59	6.07	118.45	0.002	0.066	0.268
Treat	47	4.63**	41.01*	98.67*	40.93*	38.63*	379.78**	2.15**	1.82**	91.23*	812.84**	0.050*	0.405*	2.084*
Error	94	0.35	9.16	1.42	1.56	1.69	12.65	0.47	0.15	10.88	164.38	0.006	0.042	0.117
Total	143	1.77	19.56	33.39	14.49	13.81	133.15	1.04	0.70	37.22	376.87	0.020	0.161	0.765

Table 1c Analysis of variance in 48 Tomato Genotypes for Both Season 2022-2023 and 2023-2024 (Pooled)

Source of variation	DF	Day taken to Germination	Days to 50% Flowering	Days to first fruit set	Days to first fruit maturity	Days to first fruit harvesting	Plant Height (cm)	Number of Primary Branches	Fruit Length (cm)	Number of fruits per plant	Five Fruit weight (g)	Fruit yield (kg/plant)	Fruit Yield (kg / plot)	Fruit Yield (t/ ha)
Rep.	2	0.54	0.90	0.73	0.71	0.20	2.23	0.30	0.47	5.69	318.89	0.001	0.039	0.044
Treat	47	4.49**	31.13*	100.03**	45.84*	43.96*	333.22**	1.43**	1.06**	99.77*	786.45**	0.032*	0.355*	1.969*
Error	94	0.17	3.29	0.92	1.31	1.36	10.12	0.24	0.06	4.50	64.33	0.002	0.027	0.096
Total	143	1.59	12.40	33.49	15.93	15.35	116.20	0.63	0.39	35.83	305.23	0.012	0.135	0.711

*, ** significant at 5% and 1% level, respectively

Table 2a Estimation of genetic variability of 48 genotypes of Tomato for Rabi season 2022-2023

Traits	Mean	Min	Max	Heritability (%)	GA	GA% mean	GCV (%)	PCV (%)	% cont
Day taken to Germination	12.01	8.00	15.00	83.03	3.00	24.96	13.30	14.59	8.09
Days to 50% Flowering	72.26	58.67	85.76	83.90	9.50	13.15	6.97	7.61	7.74
Days to first fruit set	46.20	35.62	57.22	93.18	11.65	25.22	12.68	13.14	5.28
Days to first fruit maturity	53.34	42.34	62.29	86.44	9.79	18.35	9.58	10.30	7.01
Days to first fruit harvesting	54.73	43.87	63.72	87.16	9.71	17.74	9.22	9.88	10.29
Plant Height (cm)	92.92	73.02	114.66	84.84	20.15	21.68	11.43	12.41	7.32
Number of Primary Branches	4.92	2.67	7.33	73.98	1.92	39.05	22.04	25.63	8.68
Fruit Length (cm)	4.73	3.14	6.44	86.45	1.57	33.32	17.40	18.71	7.10
Number of fruits per plant	66.73	52.19	79.15	91.07	14.73	22.08	11.23	11.77	5.51
Five Fruit weight (g)	275.75	215.72	314.27	84.01	40.68	14.75	7.81	8.52	7.01
Fruit yield (g/plant)	1.27	1.03	1.51	81.59	0.22	17.07	9.17	10.15	8.49
Fruit Yield (kg / plot)	3.96	3.13	4.90	79.25	0.79	20.05	10.93	12.28	9.25
Fruit Yield (t/ ha)	9.91	8.15	11.97	73.60	1.65	16.61	9.40	10.95	8.24

Table 2b Estimation of genetic variability of 48 genotypes of Tomato for Rabi season 2023-2024

Traits	Mean	Min	Max	Heritability (%)	GA	GA% mean	GCV (%)	PCV (%)	% cont
Day taken to Germination	11.85	9.18	14.33	80.10	2.20	18.58	10.08	11.26	7.19
Days to 50% Flowering	71.70	62.37	79.81	53.69	4.92	6.86	4.54	6.20	9.41
Days to first fruit set	45.85	35.64	57.64	95.82	11.48	25.04	12.42	12.69	3.75
Days to first fruit maturity	55.00	46.23	62.95	89.38	7.06	12.83	6.59	6.97	6.98
Days to first fruit harvesting	56.24	47.26	63.73	87.94	6.78	12.05	6.24	6.65	8.29
Plant Height (cm)	92.93	65.32	111.15	90.63	21.69	23.35	11.90	12.50	6.90
Number of Primary Branches	4.80	3.00	6.67	54.24	1.14	23.66	15.59	21.17	9.18
Fruit Length (cm)	4.88	3.33	6.52	79.23	1.37	28.08	15.31	17.20	6.46
Number of fruits per plant	67.08	54.66	77.88	71.12	8.99	13.40	7.71	9.15	8.55
Five Fruit weight (g)	278.94	230.37	306.89	56.80	22.83	8.18	5.27	6.99	9.61
Fruit yield (g/plant)	1.29	1.04	1.55	72.46	0.21	16.53	9.42	11.07	7.49
Fruit Yield (kg / plot)	4.03	3.10	4.80	74.46	0.62	15.34	8.63	10.00	7.69
Fruit Yield (t/ ha)	10.24	8.47	11.86	84.91	1.54	15.01	7.91	8.58	8.50

Table 2c Estimation of genetic variability of 48 genotypes of Tomato for Both Season 2022-2023 and 2023-2024(Pooled)

Traits	Mean	Min	Max	Heritability (%)	GA	GA% mean	GCV (%)	PCV (%)	% cont
Day taken to Germination	11.93	9.00	13.90	89.51	2.34	19.60	10.06	10.63	7.13
Days to 50% Flowering	71.99	65.10	80.35	73.85	5.39	7.49	4.23	4.92	8.80
Days to first fruit set	46.03	35.63	57.43	97.28	11.68	25.37	12.49	12.66	3.80
Days to first fruit maturity	54.17	44.75	62.62	91.92	7.61	14.05	7.11	7.42	7.03
Days to first fruit harvesting	55.49	46.30	63.73	91.25	7.42	13.36	6.79	7.11	7.92
Plant Height (cm)	92.93	69.31	112.73	91.41	20.44	22.00	11.17	11.68	6.75
Number of Primary Branches	4.86	3.67	6.83	62.01	1.02	20.98	12.93	16.42	10.27
Fruit Length (cm)	4.80	3.79	6.31	85.64	1.10	22.98	12.06	13.03	6.70
Number of fruits per plant	66.91	56.04	78.51	87.59	10.86	16.24	8.42	9.00	7.01
Five Fruit weight (g)	277.34	241.62	306.23	78.91	28.39	10.24	5.59	6.30	8.66
Fruit yield (g/plant)	1.28	1.11	1.50	81.59	0.18	14.39	7.74	8.56	8.11
Fruit Yield (kg / plot)	3.99	3.42	4.83	80.26	0.61	15.29	8.29	9.25	8.74
Fruit Yield (t/ ha)	10.08	8.79	11.80	86.65	1.51	15.03	7.84	8.42	9.09

PCV = Phenotypic coefficient of variation {Low (L): <10%, Moderate (M): 10-20%, High (H): >20%}

GCV = Genotypic coefficient of variation {Low (L): <10%, Moderate (M): 10-20%, High (H): >20%}

Heritability (broad sense) {Low (L):<30%, Moderate (M):30-60%, High(H):>60%}

GA=Genetic advance {Low (L):<10%, Moderate (M):10-30%, High (H):>30%}

CONCLUSION

The results of Analysis of variance revealed that for all quantitative features included for both the season, analysis of variance indicated highly significant variations among genotypes. The phenotypic and genotypic coefficient of variation ranged from 4.92% to 16.42% and 4.23% to 12.93% respectively. Higher PCV compared to GCV observed for all traits revealed that the influence of environment on traits. High heritability estimates obtained for day to first fruit set, days to first fruit maturity, plant height, days to first fruit harvesting, days taken germination, number of fruits per plant, fruit yield(t/ha), fruit length, fruit yield (kg/plant), fruit yield (kg/plot), High Genetic Advance for number of primary branch (20.98%), plant height, fruit length, days to first fruit set. High heritability coupled with High Genetic advance observed for day to first fruit set, plant height, days to first fruit set, fruit length. As yield is the most important dependent trait, day to first fruit set, plant height, days to first fruit set, fruit length can

be selected as selection parameters for further crop improvement programs.

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Conflict of interests

The authors declare that they have no competing interests.

REFERENCES

1. Anuradha, B., Saidaiyah, P., Reddy, K. R., Harikishan, S., & Geetha, A. 2020. Genetic Divergence for Yield and Yield Attributes in Tomato (*Solanum lycopersicum* L.). Green Farming, 11(4 & 5), 293-298.
2. Ara, A., Narayan, R., Ahmed, N., & Khan, S. H. 2009. Genetic variability and selection parameters for yield and quality attributes in tomato. Indian Journal of Horticulture, 66, 73-78.
3. Akhter, M., Apon, F. N., Bhuiyan, M. M. R., Siddique, A. B., Husna, A., & Zeba, N. 2021. Genetic variability, correlation coefficient, path coefficient and principal component analysis in tomato (*Solanum lycopersicum* L.) genotypes. Plant Cell Biotechnology and Molecular Biology, 22, 46-59.

4. Allard, R. W. 1960. Principles of Plant Breeding. John Wiley & Sons.
5. Bhandari, H. R., Srivastava, K., & Reddy, G. E. 2017. Genetic variability, heritability and genetic advance for yield traits in tomato (*Solanum lycopersicum* L.). *International Journal of Current Microbiology and Applied Sciences*, 6(7), 4131-4138.
6. Golani, I. J., Mehta, D. R., Purohit, V. L., Pandya, H. M., & Kazariya, M. V. 2007. Genetic variability, correlation and path coefficient studies in tomato. *Indian Journal of Agricultural Research*, 41, 146-149.
7. Hasan, M. M., Al Bari, M. A., & Hossain, M. A. 2016. Genetic variability and traits association analysis of tomato (*Lycopersicon esculentum* L.) genotypes for yield and quality attributes. *Universal Journal of Plant Science*, 4(3), 23-34.
8. Herison, C., Sutjahjo, S. H., Slastrini, I., Rustikawati, & Marwiyah, S. 2018. Genetic diversity analysis in 27 tomato accessions using morphological and molecular markers. *Journal of Agricultural Science*, 40, 36-44.
9. Islam, M. S., Mohanta, H. C., Ismail, M. R., Rafii, M. Y., & Malek, M. A. 2012. Genetic variability and trait relationship in cherry tomato (*Solanum lycopersicum* L. var. cerasiforme (Dunnal) A. gray). *Bangladesh Journal of Botany*, 41, 163-167.
10. Kaur, S., Singh, A. K., & Bagati, S. 2018. Assessment of genetic diversity in cultivated tomato (*Solanum lycopersicum* L.) genotypes using molecular markers. *International Journal of Current Microbiology and Applied Sciences*, 7, 2129-2143.
11. Kaushal, A., Singh, A., & Jeena, A. S. 2017. Genetic diversity in tomato (*Solanum lycopersicum* L.) genotypes revealed by simple sequence repeats (SSR) markers. *Journal of Applied and Natural Science*, 9(2), 966-973.
12. Kerketta, A., & Bahadur, V. 2019. Genetic Variability, Heritability and Genetic Advance for Yield and Yield Contributing Characters in Tomato (*Solanum lycopersicum* L.) Genotypes. *International Journal of Pure and Applied Bioscience*, 7(3), 577-582.
13. Kumar, P. A., Reddy, K. R., Reddy, R. V. S. K., Pandravada, S. R., & Saidaiah, P. 2016. Genetic Divergence Studies in Tomato Genotypes. *The Bioscan*, 11(4), 3071-3074.
14. Kumar, R., Bhushan, A., K Samnotra, R., Dey, T., Sharma, M., & Sharma, M. 2021. Genetic Divergence Studies in Tomato Genotypes Grown under Low-Cost Polyhouse Conditions. *International Journal of Plant & Soil Science*, 33(22), 309-313.
15. Maurya, D., Akhtar, S., Chattopadhyay, T., Kumar, R., Sahay, S., Sangam, S. and Siddiqui, M. W. 2022. Genetic variability and character association in tomato (*Solanum lycopersicum* L.). *Bangladesh Journal of Botany*, 51(4), 747-757.
16. Meena, O. P., & Bahadur, V. 2014. Assessment of genetic variability, heritability and genetic advance among tomato (*Solanum lycopersicum* L.) germplasm. *The Bioscan*, 9, 1619-1623.
17. Mihnea, N. 2015. Manifestation of variability and heritability of some quantitative characters in tomato. *Horticulture*, 59, 216-224.
18. Miller, R. H., Legates, J. E., & Cockerham, C. C. 1963. Estimation of nonadditive hereditary variance in traits of mice. *Genetics*, 48(2), 177-184.
19. Mohanty, B. K. 2002a. Studies on variability, heritability, interrelationship and path analysis in tomato. *Annals of Agricultural Research*, 23, 65-69.
20. National Horticulture Board (NHB) 2022 -2023.
21. Naveen, B. L., Reddy, K. R., & Saidaiah, P. 2018. Genetic divergence for yield and yield attributes in tomato (*Solanum lycopersicum*). *Indian Journal of Agricultural Sciences*, 88(7), 1018-1023.
22. Patel, P., Kumar, U., Maurya, P. K., Thakur, G., & Pramila. 2017. Genetic variability studies in tomato (*Solanum lycopersicum* L.). *Bulletin of Environment, Pharmacology and Life Sciences*, 6(1), 216-218.
23. Patel, S. A., Kshirsagar, D. B., Attar, A. V., & Bhalekar, M. N. 2013. Study on genetic variability, heritability and genetic advance in tomato. *International Journal of Plant Sciences*, 8(1), 45-47.
24. Robinson, H. F., Comstock, R. E. and Harvey, V. H., 1949. Estimates of heritability and degree of dominance in corn. *Agron. J.*, 41: 353-359.
25. Saravanan, K. R., Vishnupriya, V., Prakash, M., & Anandan, R. 2019. Variability, heritability and genetic advance in tomato genotypes. *Indian Journal of Agriculture Research*, 53(1), 92-95.
26. Sidhya, P., Koundinya, A. V. V., & Pandit, M. K. 2014. Genetic Variability, Heritability and Genetic Advance in Tomato. *Environment & Ecology*, 32(4B), 1737-1740.
27. Velpula, P. K., Parihar, D. S., & Pinnamaneni, R. 2017. Genetic diversity analysis of ripening specific genotypes using potential public domain SSR markers in tomato (*Solanum lycopersicum*). *Journal of Plant Breeding and Genetics*, 5(2).321-332.
28. Williams, G., & Anbuselvam, Y. 2023. Assessment of Genetic Divergence through Principal Component Analysis and Clustering in Tomato Germplasm Accessions. *Environment and Ecology*, 41(4D), 3060-3065.
29. Ziaf, K., Amjad, M., Shakeel, A., Azhar, M., & Saeed, A. 2016. Assessment of genetic diversity in tomato for fruit morphology, composition and yield. *Pak. J. Bot.*, 48(6), 2477-2483.



EFFECT OF SOIL AND SOILLESS MEDIA ON BIOCHEMICAL COMPOSITION OF LETTUCE (*LACTUCA SATIVA* L.) CULTIVARS UNDER PROTECTED CONDITION

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ABSTRACT

The investigation was conducted at the Centre for Protected Cultivation and Technology (CPCT), ICAR- Indian Agricultural Research Institute, New Delhi from 2022 to 23 to study the effects of different types of growing media on the biochemical composition of lettuce cultivars in protected conditions. It was laid in a factorial randomized block design with 3 replications. The findings of the investigation revealed that the choice of growing media significantly influenced the biochemical composition of lettuce cultivars. Soil media generally resulted in higher levels of total soluble solids, antioxidant activity, respiration rate, moisture content, chlorophyll content, and ascorbic acid content. On the other hand, soilless media performed better in terms of total carotenoid content. These findings highlight the need for proper nutrient management strategies to maximize crop yield and nutritional value. By understanding the influence of growing media on nutrient availability, farmers can implement targeted fertilization for their crops. Moreover, the study also considered the economic aspects of lettuce cultivation. It was found that soil despite providing higher yield and better-quality lettuce, required more resources and labor than soilless media. This suggests that farmers should carefully weigh the economic costs and benefits of their choice of growing media. The study provides valuable insights into the impact of growing media on lettuce cultivation. It prioritizes the need for careful selection of growing media to optimize lettuce yield and nutritional value. Additionally, it highlights the importance of sustainable agricultural practices and nutrient management in enhancing crop quality and promoting environmental sustainability.

Keywords: Soil, Soilless, Lettuce, Protected condition, Biochemical composition.

INTRODUCTION

Lettuce, a member of the Asteraceae family, is an annual plant with a chromosome count of $2n=18$. It thrives in temperate climates and originates from the Mediterranean region. Grown for its leaves, stem, and seeds, lettuce is commonly used in salads and has religious and medicinal

significance. Its consumption has spread globally, with leading production in China at 53% of the total global output (Anonymous, 2023). In India, lettuce is mainly grown in northern regions like Jammu and Kashmir, Himachal Pradesh, and Uttarakhand.

Lettuce thrives in colder seasons with moist weather conditions, temperatures

between 10-20°C, and chilly nights. It needs plenty of sunlight and nitrogen-rich soil with a pH level of 6.0-6.8. The time to maturity varies by variety and planting time, typically taking 65-130 days.

Lettuce is packed with health benefits and nutrients. It is a great source of dietary fibers, essential minerals like iron, potassium, phosphorus, calcium, and manganese, and vitamins A, B1, B6, C, and K. It is also rich in omega-3 fatty acids, which are important for growth and development. Regularly eating lettuce can prevent osteoporosis, iron deficiency, cardiovascular diseases, age-related macular diseases, Alzheimer's disease, and various cancers. Lettuce also contains bioactive compounds with medicinal properties such as anti-inflammatory, cholesterol-lowering, and anti-diabetic activities. (Oh *et al.*, 2009; Kim *et al.*, 2016).

Lettuce can be grown in soil or soilless media. Polyhouses are popular for lettuce cultivation as they protect crops and allow year-round growing. Optimal plant density in polyhouses maximizes space and resources, improving yield and quality. It also promotes efficient water and nutrient uptake through precise irrigation and fertilization. The research aimed to assess the impact of soil and soilless substrates on the biochemical composition of lettuce varieties in a controlled environment and how different growth media can affect the nutritional content and quality of lettuce.

MATERIALS AND METHODS

The experiment was conducted at the Centre for Protected Cultivation and Technology (CPCT), ICAR- Indian Agricultural Research Institute, New Delhi from November 2022 to March 2023. The climate is sub-tropical with a mean maximum temperature of 17.99° C and a mean minimum temperature of 9.9° C. The mean annual rainfall is about 33.70 mm. The experimental material 16 genotypes were obtained from

NBPGR and the private sector. The seedlings in pro trays were transferred to the main field after one month. The experiment was laid out in a Factorial Randomised Block design with three replications at a spacing of 50 cm × 20 cm in a plot size of 2.0 m × 2.0 m. Biochemical traits such as total soluble solids/TSS (° brix), antioxidant activity (DPPH inhibition %), respiration rate (ml CO₂/kg/h), moisture content (%), chlorophyll content (mg/g FW), total carotenoid content (mg/g FW) and ascorbic acid content (mg/100g) were studied and compared.

Total soluble solids/TSS was estimated by dripping the extract on the detector of the refractometer and readings were recorded.

The antioxidant activity was estimated using the DPPH assay by Blois, 1958 and Desmerchelie *et al.*, 1997. The DPPH assay involves dissolving DPPH in ethanol to a concentration of 200µM. The solution is sonicated for 5 minutes. The test compound is diluted in a 1:1 ratio with the DPPH solution in a microplate. A new DPPH solution is prepared daily. For leaf samples, 0.5g is crushed with 5 ml of ethanol and centrifuged for 20 minutes. 0.1 ml is mixed with 3.9 ml of DPPH solution from the extract. The mixture is incubated in the dark for 30 minutes. After 25 minutes, the absorbance is measured at 517 nm using a microplate spectrophotometer.

Inhibitor ratio = $(AC-AS/AC) \times 100$,

Where AC is the OD of DPPH, AS is the OD of the sample

The moisture content of the samples was determined following Ranganna's (2007) procedure. 5g samples were weighed with the container, initial weight was recorded. Samples were dried at 65°C until consistent weight, final weight was recorded. The moisture content was calculated using the following formula-

Moisture content (%) =

Leaf samples weighing 40g were finely chopped and sealed in plastic containers with

paraffin film to prevent air from escaping. CO₂ and O₂ levels were then measured for each sample. The respiration rate was calculated using the following formula

$$\text{Respiration Rate (ml CO}_2\text{/kg/h)} =$$

Chlorophyll and carotenoid levels were determined post-harvest using the DMSO technique. Leaf fragments weighing 100 mg were ground with 20 ml of DMSO and heated at 65°C for 4 hours. After centrifugation at 16000xg for 15 minutes, the supernatant was obtained. The optical density of the solution was measured at 645, 663, and 470 nm with DMSO as the control. The chlorophyll and total carotenoid content were calculated using the following formula

$$\text{Chlorophyll a} = (12.7 \times \text{OD}_{663}) - (2.69 \times \text{OD}_{645}) \times 1/1000 \times W$$

$$\text{Chlorophyll b} = (22.9 \times \text{OD}_{645}) - (4.68 \times \text{OD}_{663}) \times 1/1000 \times W$$

$$\text{Total chlorophyll} = (20.2 \times \text{OD}_{645}) - (8.02 \times \text{OD}_{663}) \times 1/1000 \times W$$

$$\text{Total Carotenoids} = (1000 \times \text{OD}_{470}) - (3.29 \times \text{Chl. a}) - (104 \times \text{Chl. b})/198$$

The ascorbic acid concentration was determined using a titrimetric technique with 2, 6-dichlorophenol indophenol dye. The leaf was crushed in HPO₃, filtered, and a 10 ml portion was titrated with the dye until a pink hue appeared. Results were reported as mg of ascorbic acid per 100 g of the sample.

$$\text{Ascorbic acid content} =$$

The data was analyzed using R 3.4.1 software from InQuest Data Analytics, Bengaluru. Any F and P values = 0.05 were considered significant.

RESULTS AND DISCUSSION

The initial step of this investigation involves examining the impact of soil and soilless media on the biochemical composition of lettuce genotypes in controlled conditions.

Except for total carotenoid content, all the biochemical compositions of lettuce genotypes grown in protected conditions exhibited better

performance in soil than in soilless media, as indicated in Table 1.

In soil, the total soluble solids/TSS (4.13° brix), antioxidant activity (42.14 DPPH inhibition %), respiration rate (1.70 ml CO₂/kg/h), moisture content (85.17 %), chlorophyll content (2.90 mg/g FW), and ascorbic acid content (17.70 mg/100g) were slightly higher than in soilless media. However, the total carotenoid content remained the same for lettuce genotypes grown in soil and soilless media (1.20 mg/g FW). The higher biochemical composition in soil-grown lettuce can be attributed to the greater nutrient availability in soil than soilless media, which ultimately supports plant growth. These findings align with the research conducted by Pace *et al.* (2018), who reported that antioxidant activity was highest in soil-grown lettuces compared to soilless-grown lettuces, and Siomos *et al.* (2001), who found that soilless-grown lettuce had lower chlorophyll content. However, these results contradict the findings of Majid *et al.* (2021) regarding TSS and chlorophyll, Gonnella *et al.* (2020) regarding chlorophyll and total carotenoid content, and Buchanan and Omaye (2013) regarding ascorbic acid content.

Romaine II had the highest TSS, moisture content, and chlorophyll content. Lollo Rossa had the highest ascorbic acid content in soilless media. Red Romaine had the highest antioxidant activity, Red Salad had a higher respiration rate, and Oak Leaf Red had the lowest TSS. Tango had the lowest antioxidant activity and ascorbic acid content, while Oak Leaf Green had the lowest respiration rate. New Red Fire had the lowest moisture content. Red Rose had lower chlorophyll content compared to Romaine I and Harit Baigani, and had the lowest total carotenoid content. Butterhead Green had the highest TSS, antioxidant activity, and ascorbic acid content among head types. Great Lakes had

the highest chlorophyll and total carotenoid content. Iceberg Salista had the highest respiration rate, while Great Lakes had the lowest TSS. Iceberg Salista had the lowest antioxidant activity. Butterhead Green had

the lowest respiration rate, moisture content, chlorophyll content, and total carotenoid content. Iceberg Crispiano had the lowest ascorbic acid content.

Table 1 Effect of growing media on biochemical composition of lettuce genotypes

Treatments	Total soluble solids/TSS (° brix)			Antioxidant activity (DPPH inhibition %)			Respiration rate (ml CO ₂ /kg/h)			Moisture content (%)			Chlorophyll content (mg/g FW)			Total carotenoid content (mg/g FW)			Ascorbic acid content (mg/100g)		
	M ₁	M ₂	Mean	M ₁	M ₂	Mean	M ₁	M ₂	Mean	M ₁	M ₂	Mean	M ₁	M ₂	Mean	M ₁	M ₂	Mean	M ₁	M ₂	Mean
V ₁ – Romaine I	3.15	2.97	3.06	25.31	25.16	25.24	1.04	0.86	0.95	83.51	83.32	83.42	2.02	1.97	1.99	0.54	0.49	0.52	13.52	13.37	13.45
V ₂ – Romaine II	6.64	6.46	6.69	24.22	24.07	24.15	1.59	1.41	1.31	89.26	89.07	89.17	4.19	4.14	4.17	1.28	1.23	1.26	17.49	17.34	17.42
V ₃ – Tango	3.42	3.24	3.30	24.18	24.03	24.11	1.69	1.51	1.59	87.72	87.53	87.89	4.11	4.06	4.09	1.03	0.98	1.01	12.37	12.22	12.30
V ₄ – Oak Leaf Green	3.95	3.77	3.86	27.16	27.01	27.09	1.03	0.85	0.94	86.05	85.86	85.96	4.01	3.96	3.99	0.94	0.89	0.92	21.32	21.17	21.25
V ₅ – Grand Rapids	5.35	5.17	4.57	34.36	34.21	34.29	2.46	2.28	2.37	85.32	85.13	85.23	3.03	2.98	3.01	0.72	0.67	0.70	17.39	17.24	17.32
V ₆ – Harit Baigani	4.95	4.77	4.86	35.71	35.56	35.64	2.06	1.88	1.12	84.57	84.38	86.41	2.13	2.08	2.11	0.42	0.39	0.52	12.66	12.51	12.59
V ₇ – Oak Leaf Red	2.05	1.87	2.34	53.54	53.39	53.47	1.55	1.37	1.15	84.63	84.44	84.54	2.87	2.82	2.85	1.54	1.49	1.52	17.58	17.43	17.51
V ₈ – Red Romaine	2.89	2.71	2.8	64.04	63.89	63.97	1.54	1.36	1.19	84.36	84.17	87.31	2.08	2.03	2.06	1.43	1.38	1.41	13.14	12.99	22.28
V ₉ – Lollo Rossa	3.35	3.17	3.26	62.44	62.29	62.37	2.33	2.15	1.26	94.41	94.22	93.79	4.09	4.04	4.07	1.42	1.37	1.40	27.61	27.46	27.54
V ₁₀ – New Red Fire	5.35	5.17	5.54	30.81	30.66	30.74	1.93	1.75	1.84	83.05	82.86	82.96	1.97	1.92	1.95	1.32	1.26	1.29	23.08	22.93	23.01
V ₁₁ – Red Salad	3.55	3.37	3.47	63.31	63.16	63.24	2.49	2.31	2.4	83.01	82.82	84.33	1.96	1.91	1.94	2.42	2.37	2.40	17.58	17.43	17.51
V ₁₂ – Red Rose	4.15	3.97	4.06	64.21	64.06	64.14	1.07	0.89	0.98	82.21	82.02	84.67	1.87	1.82	1.85	2.26	2.21	2.24	23.14	22.99	23.07
V ₁₃ – Iceberg Salista	4.15	3.97	4.07	35.14	34.99	35.07	2.25	2.07	2.01	84.44	84.25	84.82	3.01	2.96	2.99	1.13	1.08	1.11	14.04	13.89	26.18
V ₁₄ – Iceberg Crispiano	4.55	4.37	4.46	36.57	36.42	36.50	1.56	1.38	1.17	82.92	82.73	82.83	2.96	2.91	2.94	1.11	1.06	1.09	16.42	16.27	14.92
V ₁₅ – Butterhead Green	5.09	4.91	5.77	57.31	57.16	57.24	1.09	0.91	0.89	82.67	82.48	82.58	2.73	2.68	2.71	1.01	0.96	0.99	17.91	17.76	23.07
V ₁₆ – Great Lakes	3.48	3.30	3.39	35.87	35.72	35.80	1.53	1.35	1.44	84.67	84.48	86.08	3.41	3.36	3.39	1.14	1.09	1.12	17.89	17.74	17.70
Mean	4.13	3.95	4.09	42.14	41.99	42.06	1.70	1.52	1.36	85.17	84.98	85.74	2.90	2.85	2.88	1.20	1.20	1.20	17.70	17.55	19.19

M₁ – Soil

M₂ – Soilless

CONCLUSION

Based on the research findings, it can be concluded that soil is the preferred medium for lettuce cultivation.

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REFERENCES

1. Anonymous. (2023). Lettuce (with chicory) production in 2021; Countries/ Regions/ Production Quantity from pick lists. UN Food & Agriculture Organization, Statistics Division (FAOSTAT). Retrieved 12th April 2023.
2. Blois, M.S. (1958). Antioxidant determinations by the use of a stable free radical. *Nature*, 181, 1199-1200.
3. Buchanan, D.N. & Omaye, S.T. (2013). Comparative study of ascorbic acid and tocopherol concentrations in hydroponic and soil grown lettuces.
4. Desmarchelier, C., Novoa Bermudez, M. J., Coussio, J., Ciccio, G. & Boveris, A. (1997). Antioxidant and prooxidant activities in aqueous extracts of Argentine plants. *International Journal of Pharmacognosy*, 35(2), 116-120.
5. Gonnella, M., Renna, M. & Serio, F. (2020). Yield and quality of greenhouse multi-leaf lettuce cultivars grown in soil and soilless culture under Mediterranean conditions. *Italus Hortus*, 27, 18-30.
6. Kim, M. J., Moon, Y., Tou, J., Mou, B. & Waterland, N. (2016). Nutritional value, bioactive compounds and health benefits of lettuce (*Lactuca sativa* L.): study review. *J. Food Composition and Analysis*, 49, 19-34.
7. Majid, M., Khan, J. N., Shah, Q. M. A., Masoodi, K. Z., Afroza, B. & Parvaze, S. (2021). Evaluation of hydroponic systems for the cultivation of Lettuce (*Lactuca sativa* L., var. *Longifolia*) and comparison with protected soil-based cultivation. *Agricultural Water Management*, 245, 106572.
8. Oh, M. M., Trick, H. N. & Rajashekar, C. B. (2009). Secondary metabolism and antioxidants are involved in environmental adaptation and stress tolerance in lettuce. *Journal of Plant Physiology*, 166(2), 180-191.
9. Pace, B., Capotorto, I., Gonnella, M., Baruzzi, F. & Cefola, M. (2018). Influence of soil and soilless agricultural growing system on postharvest quality of three ready-to-use multi-leaf lettuce cultivars. *Advances in Horticultural Science*, 32(3), 353-362.
10. Ranganna, S. (2007). Handbook of analysis and quality control for fruits and vegetable products. Tata McGraw-Hill.
11. Selma, M. V., Luna, M. C., Martínez-Sánchez, A., Tudela, J. A., Beltrán, D., Baixauli, C. & Gil, M. I. (2012). Sensory quality, bioactive constituents and microbiological quality of green and red fresh-cut lettuces (*Lactuca sativa* L.) are influenced by soil and soilless agricultural production systems. *Postharvest Biology and Technology*, 63(1), 16-24.
12. Siomos, A.S., Beis, G., Papadopoulou, P.P., Nasi, P., Kaberidou, I., Barbayiannis, N., Maloupa, E. & Gerasopoulos, D. (2001). Quality and composition of lettuce (cv. 'Plenty') grown in soil and soilless culture.



CHARACTERIZATION AND EVALUATION OF DIFFERENT GERMPLASM OF VEGETABLE MUSTARDS (SAAG SARSON) FOR NORTH WEST PLAIN ZONE OF UTTAR PRADESH

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ABSTRACT

The present investigation entitled “Characterization and Evaluation of Various Germplasm of Vegetable Mustards (Saag Sarson) for NWPZ of UP” was conducted during the rabi season of 2019-20 and 2020-21 at the Horticultural Research Centre under the Sardar Vallabhbhai Patel University of Agriculture and Technology. The experiment was designed using a Randomized Block Design (RBD) with three replications and included different five germplasms of vegetable mustard (Saag Sarson) i.e., G₁ Pusa Saag Sarson, G₂ Local Collection-1, G₃ Local Collection-2, G₄ Local Collection-3 and G₅ Local Collection-4. Promising germplasm accessions were identified for different eleven morpho-economic and biotic stress traits, which may be useful for vegetable mustards (Saag Sarson) commercial cultivation in NWPZ of UP. The result revealed the significance of various parameters of vegetable mustards. In the experiment, it was concluded that germplasm G₁ Pusa Saag Sarson exhibited superior performance for most of the parameters such as days to germination %, leaf weight (gm) of 5 leaves per plot, leaf width (cm), leaf length (cm), seed weight (kg) per plot, disease powdery mildew free, disease alternaria free with the best value than rest of germplasms. Among the germplasm, germplasm G₂ Local Collection-1 recorded the highest value of parameters such as days to 50 % flowering, plant height (m) and germplasm G₄ Local Collection-3 recorded the highest value such as Leaf weight (gm) per 5 plants, number of leaves per plant as compared to rest of germplasms. Among the five germplasms evaluated, the highest seed weight (kg) per plot was recorded at germplasm G₁ Pusa Saag Sarson and is best for developing the planting material of vegetable mustard for crop improvement. It is also best as maximum parameters are covered for the diversification of traditional crops as compared to the rest of the germplasms. The germplasm G₁ Pusa Saag Sarson vegetable mustard has the potential for cultivation in humid tropical and subtropical climates in Uttar Pradesh, India.

Keywords: *Characterization, Germplasm, Evaluation, Crop improvement, Vegetable Mustard*

INTRODUCTION

Vegetable mustard, scientifically known as *Brassica juncea* (L.) Czern and Coss, is a significant leafy vegetable crop during the rabi season. Saag sarson, a type of mustard plant belonging to the Brassicaceae (Cruciferae) family, is a common species of vegetable mustard. This crop is rich in nutrients, vitamins, and minerals. Mustard greens come in many varieties with varying leaf size, shape, and color, ranging from green to red to purple. The beautiful color and texture of mustard greens make them an excellent addition to any dish. Mustard greens are particularly famous for delicacies such as 'Sarson ka saag'. Dehydrated mustard greens are also available in the market (Pruthi 2001). Mustard seeds are used as a spice (20) and condiment and have a wide range of flavors, from sweet to spicy, and varying levels of pungency (Hirasa and Takemasa 1998). The most important content responsible for the flavor and pungency of mustard oil is isothiocyanates (17). Mustard oil is used in soap making and as a lubricant and illuminant (12). Unfortunately, many fungal diseases, such as Alternaria leaf blight and powdery mildew, can cause significant damage to the crop (21). Major players in the area and production of Indian Mustard include Rajasthan, Madhya Pradesh, Uttar Pradesh, Bihar, Gujarat, and West Bengal. Despite its popularity, the full potential of this crop in India is challenging to exploit due to various biotic and abiotic stresses. Mustard seeds are typically sown in March to April, with harvesting taking place in September. Farmers must harvest the crop before the pods are fully ripe to prevent the seeds from spilling out. Plant breeding has allowed farmers to produce consistently high-quality seeds. However, there have been no attempts so far to study the various morpho-economic and biotic stress parameters identified for vegetable mustard germplasms.

MATERIALS AND METHODOLOGY

The research study was carried out during the rabi season of years 2019-20 and 2020-21 at the Horticulture Research Centre (HRC) affiliated with Sardar Vallabhbhai Patel University of Agriculture and Technology. The experimental design utilized in this study was a Randomized Block Design (RBD) with three replications and including different five germplasm of vegetable mustard (Saag Sarson) i.e., G₁ Pusa Saag Sarson, G₂ Local Collection-1, G₃ Local Collection-2, G₄ Local Collection-3 and G₅ Local Collection-4 were used in the study by adopting Randomized Block Design (RBD) replicated thrice having four plants per germplasm. The details of the germplasms schedule are presented in Table 1 and Fig. 1. For characterization and evaluation of different germplasm of vegetable mustard (Saag Sarson) were sown in rabi Season during 2019-20 and 2020-2021. The data presented in the table represents the mean value of two years. A plot size of 5 × 3 m was utilized with a plant to plant and row to row distance of 20 cm and 45 cm, respectively. The recommended package of practices was uniformly adopted for all germplasms. Observations on eleven morpho-economic and biotic stress parameters were recorded using five randomly selected competitive plants from each variety in each replication.

The percentage of the day to germination and 50% flowering were noted on a per-plot basis. For leaf weight (grams), five leaves were chosen from each germplasm and their mean was recorded. Similarly, leaf width and length (centimeters) were measured with slide callipers, taking five leaves at random from each variety. Plant height (in meters) was measured for five randomly selected plants per plot, from ground level to the plant tip, and recorded in centimeters. Seed weight (kilograms) per plot was determined by

harvesting produce from the net plot area and sun-drying it before threshing and cleaning. Leaf weight (grams) per five plants and the number of leaves per plant were also recorded per germplasm. Disease observation of *Alternaria* blight was conducted weekly at random on five plants per plot per variety, using a rating scale as described by Bal and Kumar (2013). To evaluate powdery mildew incidence, a scoring scale (0-3) was developed: 0 indicating no infection, 1 indicating less than five small spots, 2 indicating five to twenty spots, and 3 indicating widespread powdery mildew with dense sporulation (4). Statistical analysis was performed on the recorded observations following the standard procedure recommended by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

The data presented in Table 1 and Fig. 1 on vegetable mustard revealed significant variations for various germplasm. The vegetable mustard parameters such as days to germination %, leaf weight (gm) of 5 leaves/plot, leaf width (cm) and leaf length (cm) was significantly highest (90%, 433.33gm, 29.86cm, 65.23cm respectively) in the G₁ Pusa Saag Sarson than rest of germplasms.

Among the five germplasms evaluated, the maximum days to germination % was recorded at 90% in Pusa Saag Sarson followed by 88.33% (Local Collection-1), 86.66% (Local Collection-4), 83.33% (Local Collection-2) and that minimum in Local Collection-3(80%). The vegetable mustard days to 50 % flowering was recorded significantly maximum in Local Collection-1(103%) and minimum in germplasm Local Collection-4(74.33%). The duration from sowing to germination and flowering plays a crucial role in crop establishment and reproductive performance.

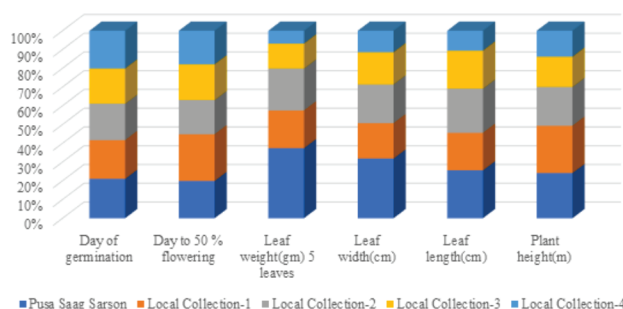
Recent research by Gupta et al. (2022) evaluated different Saag Sarson germplasm lines for their day-to-germination and day-to-50 % flowering. The study revealed significant variation among the accessions, indicating differences in their early growth and reproductive development.

The vegetable mustard leaf weight (gm) of 5 leaves per plot ranged from minimum of Local Collection-4 (80gm) to maximum of Pusa Saag Sarson (433.33gm). Significantly lowest vegetable mustard leaf weight (gm) of 5 leaves per plot was recorded in Local Collection-4 (80gm) followed by Local Collection-2 (19.46cm) and Local Collection- 1 (17.66cm). Significantly lowest leaf width was recorded for Local Collection-4 (10.80cm) among the germplasms. The germplasm G₁ Pusa Saag Sarson recorded significantly maximum leaf length (65.33cm) which were closely followed by Local Collection-2 (60.26cm). Significantly lowest leaf length was recorded in G₃ Local Collection-4 (27.20) among the different germplasms. Morphological characteristics such as leaf weight, leaf width, and leaf length are important indicators of plant vigor and biomass production. In a study conducted by Verma and Singh (2023), 15 Saag Sarson accessions were evaluated for leaf weight (measured as the weight of 5 leaves per plot), leaf width, and leaf length. The results showed substantial variation among the accessions, suggesting the potential for selecting lines with desirable leaf traits for enhanced biomass production.

The germplasm G₂ Local Collection-1 recorded a significantly maximum of plant height of (2.93m) which were closely followed by Pusa Saag Sarson (2.80 m), Local Collection-2 (2.41 m). The germplasm G₄ Local Collection-3 recorded significantly minimum plant height (1.62 cm) among the tested germplasms.

Table 1. Mean value of characterization and evaluation of different germplasm of vegetable mustards (Saag Sarson)

Variety	Day to germination %	Day to 50 % flowering	Leaf weight (gm) of 5 leaves/plot	Leaf width (cm)	Leaf length (cm)	Plant height (m)
Pusa Saag Sarson	90	82.33	433.33	29.86	65.33	2.8
Local Collection-1	88.33	103	233.33	17.66	51.06	2.93
Local Collection-2	83.33	75.66	260	19.46	60.26	2.41
Local Collection-3	80	78.66	153.33	16.06	51.73	1.86
Local Collection-4	86.66	74.33	80	10.8	27.2	1.62
SE(m)	2.47	1.89	39.07	1.59	3.24	0.27
SE(d)	3.49	2.68	55.24	2.26	4.59	0.39
C.D.	N.S.	6.17	130.83	5.2	10.57	0.9
CV%	4.99	3.96	29.98	14.74	10.99	20.72

**Fig. 1 Mean value of characterization and evaluation of different germplasm of vegetable mustards (Saag Sarson)**

In Table 2 and Fig. 2, among the five germplasms, significantly the highest seed weight per plot was recorded in germplasm G₁ Pusa Saag Sarson (2.20 kg). Other closely followed by Local Collection-2 (2.11 kg), Local Collection-4 (1.93kg), Local Collection-1 (1.83kg) and Local Collection-3 (0.86 kg). Plant height and seed weight are key agronomic traits that contribute to crop yield. A recent study by Sharma et al. (2023) investigated the variation in plant height and seed weight among different Saag Sarson varieties. The research demonstrated significant differences in plant height, indicating variations in plant architecture,

while also revealing variations in seed weight, reflecting potential differences in yield potential among the accessions.

Among the five germplasms, significantly highest leaf weight per 5 plant was recorded in germplasm Local Collection-3 (1954gm) followed by Pusa Saag Sarson (1730gm), Local Collection-1 (1327gm), Local Collection-2 (1322gm), Local Collection-4 (401gm). The germplasm Local Collection-3 recorded significantly maximum the number of leaves per plant of G₄(59) which were closely followed by Local Collection-1(27), Local Collection-2 (26.66) and Local Collection-4(22.33). The germplasm G₁ Pusa Saag Sarson recorded significantly minimum number of leaves per plant (21.33) among the tested germplasms. Assessing leaf weight per 5 plants and the number of leaves per plant provides insights into the overall leaf biomass and productivity of Saag Sarson varieties. Mishra and Verma (2022) conducted a study to evaluate leaf weight per 5 plants and the number of leaves per plant in various Saag Sarson germplasm lines. The findings highlighted significant variations among the accessions, indicating differences in leaf biomass accumulation and leaf production capacity.

Among the five germplasms evaluated, the significantly highest pathogen susceptibility of powdery mildew disease was observed at germplasm G₄ Local Collection-3 (2), Local Collection-4 (2) and other germplasms observed that germplasm G₁ Pusa Saag Sarson, G₂ Local Collection-1 and G₃ Local Collection-2 were disease free. The germplasm G₅ Local Collection-4 observed significantly highest pathogen susceptibility of Alternaria disease and other germplasm i.e. G₁ Pusa Saag Sarson, G₂ Local Collection-1, G₃ Local Collection-2 and G₄ Local Collection-3 were disease free. Biotic stress, particularly diseases such as Powdery Mildew and Alternaria, can significantly impact crop yield

and quality. Recent research by Khan et al. (2022) examined the incidence and severity of Powdery Mildew and *Alternaria* in different Saag Sarson varieties. The study revealed variations in disease resistance among the accessions, suggesting the presence of potential sources of resistance that can be used in breeding programs for disease-resistant varieties.

The mustard plant is highly susceptible to fluctuations in weather conditions, which are predicted to have adverse effects on its production due to climate change (Kumar et al., 2010). Daily fluctuations in maximum and minimum temperatures, which have an impact on plant physiological, biochemical, and metabolic activities, are the primary negative effects of climate change on vegetable production. High temperatures have a significant influence on vegetable production in tropical and dry environments, affecting plant growth, development, and yield through morphological, physiological, biochemical, and molecular responses. Warm and humid conditions promote vegetative growth, but high temperatures lead to the abscission of flower buds, blooms, and immature pods, reducing pod production, mature pod size, and seeds per pod (Abewoy 2018). Temperature increases also lead to a decrease in yield, as found in studies on mustard (11, 9), vegetable crops (18), and mustard (Nagarajan et al. 2007).

The agriculture sector, which is of global importance, was one of the first sectors to be studied for potential climate change consequences (1). Temperature, carbon dioxide, and ozone all have direct or indirect impacts on the productivity and quality of vegetable crops grown in various regions worldwide. Temperature changes directly affect crop photosynthesis, and a rise in global temperatures is projected to significantly impact postharvest quality by modifying essential quality metrics such as sugar and

organic acid synthesis, antioxidant chemicals, and firmness. Increased ozone levels in the atmosphere can negatively affect the postharvest quality of fruit and vegetable crops. Any environmental anomaly resulting from climate change can place unprecedented stress on the growth and development process of vegetable crops, potentially resulting in crop failure. Optimum productivity is constrained by several limiting factors, such as extreme temperatures, limited soil moisture, reduced irrigation water availability, repeated flooding, increased acidity or salinity and soil erosion, high wind speed, increased occurrence of hail and thunderstorms, frost damage, and tsunamis. Sudden changes in climate can also influence soil fertility, the occurrence of pests and diseases, host-pathogen interactions, soil microbial population, and pollinator behavior. The ultimate result of climate change is reduced production and productivity due to the emergence of genetically weaker seeds, as found in studies on vegetables (19) and fruit and vegetables (14), and mustard.

The findings of this study are consistent with previous research on the importance of germplasm evaluation and characterization for the development of improved crop varieties (Gul et al., 2019; Singh et al., 2015). The identification of germplasm accessions with desirable traits is essential for the breeding of improved crop varieties that can withstand biotic and abiotic stresses, increase productivity, and enhance the nutritional value of crops. Additionally, the results of this study highlight the potential of Saag Sarson as a profitable crop in the NWPZ of Uttar Pradesh, which could contribute to the economic development of the region. The study conducted by Singh et al. (2020) provides valuable information on the characterization and evaluation of different germplasms of Saag Sarson for commercial cultivation in the NWPZ of Uttar Pradesh. The identification of

promising germplasm accessions with desirable morpho-economic and biotic stress traits could contribute to the development of improved crop varieties that can enhance the productivity and profitability of Saag Sarson cultivation in the region. Further research on the genetic basis of the identified traits is necessary for the development of improved Saag Sarson varieties.

Table 2 Mean value of characterization and evaluation of different germplasm of vegetable mustards (Saag Sarson)

Variety	Seed weight (Kg)/plot	Leaf weight (gm)/ 5 plant	Number of leaves per plant	Disease Powdery Mildew	Disease Alternaria
Pusa Saag Sarson	2.2	1730	21.33	0	0
Local Collection-1	1.83	1327	27	0	0
Local Collection-2	2.11	1322	26.66	0	0
Local Collection-3	0.86	1954	59	2	0
Local Collection-4	1.93	401	22.33	2	3
SE(m)	0.2331	144.66	4.84	0.14	0.14
SE(d)	0.3296	204.56	6.85	0.21	0.21
C.D.	0.7583	471.22	15.79	0.48	0.48
CV%	22.55	18.6	26.85	26.85	35.45

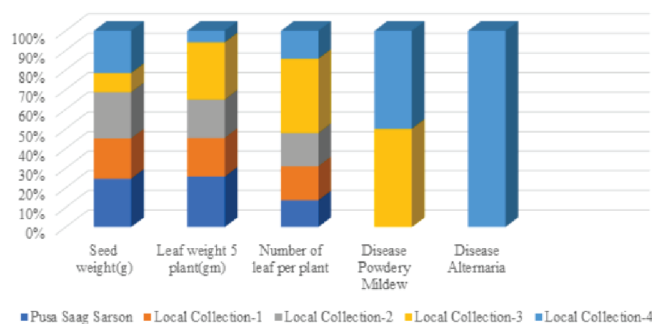


Fig. 2 Mean value of characterization and evaluation of different germplasm of vegetable mustards (Saag Sarson)

CONCLUSION

In the experiment, it is concluded that germplasm G₁ Pusa Saag Sarson exhibited superior performance for most of the parameters such as days to germination %, leaf weight (gm) of 5 leaves per plot, leaf width (cm), leaf length (cm), seed weight (kg) per

plot, disease powdery mildew free, disease Alternaria free. Among the germplasms, germplasm G₂ Local Collection-1 recorded highest value of parameters such as days to 50 % flowering, plant height (m) and germplasm G₄ Local Collection-3 recorded the highest value of parameters such as leaf weight (gm) per 5 plant, number of leaves per plant as compared to rest of treatments. Among the five varieties evaluated, the highest seed weight (kg) per plot was recorded at germplasm G₁ Pusa Saag Sarson and is best for developing the planting material of vegetable mustard for crop improvement. It is also best as the maximum parameters covered for the diversification of traditional crops as compared to the rest of the varieties. The germplasm G₁ Pusa Saag Sarson vegetable mustard has the potential for cultivation in humid tropical and subtropical climates in Uttar Pradesh, India.

AUTHORS CONTRIBUTION

In the preparation of my manuscript, all authors played an important role in providing valuable suggestions and ideas for improving its content and structure. Their contributions helped to refine the research findings and to present them in a clear and concise manner. This collaborative effort demonstrates the authors' commitment to producing a high-quality manuscript that accurately represents the research findings and contributes to the scientific community.

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REFERENCES

1. Abewoy, D. (2018). Review on impacts of climate change on vegetable production and its management practices. *Advances in Crop Science and Technology*, 6(01), 1-7.
2. Adams, R. M., Rosenzweig, C., Peart, R. M., Ritchie, J. T., McCarl, B. A., Glycer, J. D., & Allen Jr, L. H. (1990). Global climate change and US agriculture. *Nature*, 345(6272), 219-224.
3. Bal, R. S., & Kumar, A. (2014). Studies on the epidemiology of white rust and Alternaria leaf blight and their effect on the yield of Indian mustard. *African Journal of Agricultural Research*, 9(2), 302-306.
4. Barba, P., Cadle-Davidson, L., Galarneau, E., & Reisch, B. (2015). Vitis rupestris B38 confers isolate-specific quantitative resistance to penetration by Erysiphe necator. *Phytopathology*, 105(8), 1097-1103.
5. Farooqi, A. A., Sreeramu, B. S., & Srinivasappa, K. N. (2005). *Cultivation of spice crops*. Universities press.
6. Gul, F., Raziuddin, R., Ali, S., & Hussain, M. (2019). Evaluation of different brassica germplasm for resistance against Alternaria blight. *Pure and Applied Biology*, 8(4), 313-323.
7. Gupta, A., Kumar, S., Sharma, R., & Singh, P. (2022). Evaluation of Saag Sarson germplasm for morphological and flowering traits. *Journal of Crop Science*, 10(2), 123-130.
8. Hirasa, K., & Takemasa, M. (1998). *Spice science and technology*. CRC Press. Marcel Dekker Inc. New York pp. 9-16.
9. Kalra, N., Chakraborty, D., Sharma, A., Rai, H. K., Jolly, M., Chander, S., & Sehgal, M. (2008). Effect of increasing temperature on yield of some winter crops in northwest India. *Current science*, 82-88.
10. Khan, S., Verma, A., Mishra, R., & Singh, V. (2022). Assessment of disease incidence and severity in Saag Sarson (*Brassica juncea*) germplasm. *International Journal of Plant Pathology*, 11(3), 97-105.
11. Kumar, G., Chakravarty, N. V. K., Kurothe, R. S., Sena, D. R., Tripathi, K. P., Adak, T., & Haldar, D. (2010). Effect of projected climate change on mustard (*Brassica juncea*). *Journal of Agrometeorology*, 12(2), 168-173.
12. Leung, A. Y., & Foster, S. (1996). Encyclopedia of common natural ingredients used in food, drugs, and cosmetics.
13. Mishra, R., & Verma, A. (2022). Evaluation of leaf weight and leaf production in Saag Sarson (*Brassica juncea*) germplasm lines. *Indian Journal of Horticulture*, 79(1), 84-89.
14. Moretti, C. L., Mattos, L. M., Calbo, A. G., & Sargent, S. A. (2010). Climate changes and potential impacts on postharvest quality of fruit and vegetable crops: A review. *Food Research International*, 43(7), 1824-1832.
15. Verma, O. P., Ram Bhajan, R. B., & Singh, H. P. (2001). Association among seedling and yield contributing traits in mustard. *Cruciferae Newsletter*, 23, 49-50.
16. Panse, V. G., & Sukhatme, P. V. (1967). *Statistical Methods for Agricultural Workers*, ICAR, New Delhi.
17. Park, K. Y., Kwon, D. Y., Lee, K. W., & Park, S. (Eds.). (2018). *Korean functional foods: composition, processing and health benefits*. CRC Press.
18. Peet, M. M., & Wolfe, D. (2000). Vegetable crop responses to climatic change. *Climate Change and Global Crop Productivity*, CABI Publishing: Wallingford, UK, 213-243.
19. Prasad, B. V. G., & Chakravorty, S. (2015). Effects of climate change on vegetable cultivation-a review. *Nature Environment and Pollution Technology*, 14(4), 923.
20. Pruthi, J. S. (2001). Minor spices and condiments: crop management and post-harvest technology. *Minor spices and condiments: crop management and post-harvest technology*. ICAR, New Delhi, pp. 242-54.
21. Shahid, S. (2013) Seed Borne Mycoflora of Indian Mustard (*Brassica juncea*): Mustard Seed Mycoflora. Lambert Academic Publishing.
22. Sharma, R., Singh, P., Kumar, S., & Gupta, A. (2023). Variation in plant height and seed weight among Saag Sarson (*Brassica juncea*) varieties. *Journal of Agriculture and Rural Development*, 15(1), 45-52.
23. Singh, N., Kumar, V., Kumar, A., Singh, R., Singh, S. K., & Singh, S. (2020). Characterization and evaluation of different germplasm of vegetable mustards (Saag Sarson) for North West Plain Zone of Uttar Pradesh. *Indian Journal of Agricultural Sciences*, 90(9), 136-141.
24. Singh, R., Chaudhary, B. D., & Singh, K. P. (2015). Genetic divergence in Indian mustard (*Brassica juncea* L. Czern & Coss) germplasm collection. *Indian Journal of Agricultural Sciences*, 85(5), 721-725.
25. Srivastava, K. K., Vimal, S. C., Giri, S. P., & Verma, A. K. (2016). Studies on seed quality parameters in Indian mustard [*Brassica juncea* (L.) Czern and Coss]. *International Journal of Agricultural Sciences*. 12(2):241-244.
26. Verma, A., & Singh, V. (2023). Morphological characterization of Saag Sarson (*Brassica juncea*) germplasm for leaf traits. *Journal of Crop Improvement*, 27(1), 56-65.



EFFECT OF DIFFERENT COLOUR SHADE NETS ON GERMINATION AND SEEDLING GROWTH OF PAPAYA (*CARICA PAPAYA*) VAR. GJP-1

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ABSTRACT

A research study was undertaken at the College Nursery, Department of Horticulture, N. M. College of Agriculture, Navsari Agricultural University, Navsari, during the years 2018-2022 to investigate the impact of various color shade nets on the germination and seedling growth of papaya (*Carica papaya* L.) var. GJP-1. The experiment was conducted in Completely Randomized Design (CRD) design with six distinct treatments, each replicated three times. The papaya variety Gujarat Junagadh Papaya-1 was sown in plug tray using Red soil + FYM + Vermicompost (2:1:1) as growing media. In this investigation, various colors including red, white, green, blue, yellow and a control, each with 50% shade net intensity, were employed as treatments. The findings, based on the three-year mean, revealed a note worthy significance in the germination and seedling growth of papaya within the white shade net as compared to other color. The earlier germination (16.21) and highest survival percentage (60.00%) were found in white colour shade net whereas maximum seedling height (6.13 cm and 11.75 cm, respectively), seedling diameter (1.20 mm and 2.32mm, respectively) and No. of leaves (6.27 and 8.69, respectively) at 30 DAS and 45 DAS was recorded in white colour shade net. In case of photosynthesis rate and light intensity, significantly higher value of photosynthesis rate ($468.40 \mu\text{mol CO}_2\text{m}^{-2}\text{s}^{-1}$) and lower light intensity ($320.10 \mu\text{mol m}^{-2}\text{s}^{-1}$) were also observed in same treatment. The light intensity slowly increased and reached peak at 12.30 hrs then decreased slowly up to 17.00 hrs in all shade nets. The lower temperature and higher Relative Humidity (RH) were obtained in different colour structure as compared to open condition.

Keywords: Papaya seedlings, shade nets, germination, survival and photosynthesis rate

INTRODUCTION

Papaya (*Carica papaya L.*) is a delicious tropical fruit, known as Melon tree, Pawpaw fruit, Breakfast fruit and Backyard fruit which belongs to family Caricaceae. Papaya holds a prominent position among the all essential fruit crops grown in both tropical and subtropical regions, boasting significance not only for its higher remuneration but also for easy of cultivation and increased production per unit area. Its nutritional profile is remarkable, featuring a substantial content of vitamin A - 2020 IU/100g (3). Additionally, papaya is also rich in vitamin B, folate and pantothenic acid, along with essential minerals like potassium and magnesium (12). The fruits being a valuable source of beta-carotene, potentially contributing to the prevention of ailments such as cancer, diabetes and heart disease (1).

Papaya plants are traditionally established with seedlings previously grown in a nursery. A nursery allows cultivation and establishment of seedlings under protected conditions. But, the growing conditions under the nursery setup are under the control of the nurseryman. Hence, the quality of seedlings is inherently linked to the cultural practices implemented by the nurseryman. According to Lamont and O'Connell (1987), the overall importance of container-grown plants is in broad terms, dependent on the physical and chemical characteristics of the growing medium, the surrounding environment and other plant management such as, watering, insect-pests and disease control. A novel approach involves the use of color nets, which offer both physical protection and selective filtration of solar radiation which encourage specific physiological responses. The application of solar radiation by various plants is influenced by the distinctive optical properties of color shade nets, altering the natural radiation's quality. The incorporation of shade nets is aimed at optimizing desired

physiological responses, providing physical protection and significantly influencing the growth, shoot elongation, survival and flowering in several plants (10).

Shade net is a good approach to minimize the direct exposure of plant to sunlight. Secondly, it also helps to maintain micro-climatic conditions during high as well low temperatures and thus, helps to maintain normal physiological activities and seedling quality also (12). Shade nets not only diminish the quantity of light but also responsible for alteration of light quality, which altering other environmental conditions (17). Various color shade nets demonstrate a reduction in radiation reaching the crops below, directly correlating with the shade factor and altering the micro-environment. Hence, the research conducted to evaluate the effect of colour shade nets on seedling emergence, seedling quality and early growth of papaya at nursery stage during summer season.

MATERIAL AND METHODS

The experiment was carried out at College Nursery, Department of Horticulture, N. M. College of Agriculture, Navsari Agricultural University, Navsari during the year 2018-2022. The seeds of papaya variety Gujarat Junagadh Papaya-1 (GJP-1) was purchased from Junagadh Agricultural University, Junagadh. The trial was conducted in a Completely Randomized Design (CRD) design with six treatments, T₁ - Red colour, T₂ - White colour, T₃ - Green colour, T₄ - Blue colour, T₅ - Yellow colour and T₆ - Control (with 50% net intensities) and three replications. 100 seeds were sown in plug tray (6cm depth x 5cm diameter) media comprising of Red soil + FYM + Vermicompost in (2:1:1). The seedlings were sown during summer season (March month) and all the plug trays were kept under shade net structures. Immediately after sowing light irrigation was given with watering cane

comprising of a fine rose. The observations on the different parameters listed below were observed on daily base for all growth and germination parameters. The seedling height, seedling diameter and number of leaves were taken at 30 and 45 days after sowing. The height of seedling was measured by metric scale from the ground level to the highest growing point of the seedlings and seedling diameter was measured with the help of vernier caliper at height 1 cm above the ground level and average value was recorded. The number of leaves per seedling be counted and average value was worked out. In case of days taken for germination, number of days required for germination was counted every day start from seed sowing to completion of germination and calculated the average. The leaf photosynthesis rate was recorded with the help of LI-6400XT Portable Photosynthesis and Fluorescence System instrument. The air temperature and relative humidity inside the nursery shades were measured at about 1.5m above the ground level during every morning hours at 7.30 am while the light intensity reading was recorded at 15 minute interval starting from 9:00 hrs up to 17.00 hrs consecutively for entire period (twice in a week). Light intensity was measured using LUX meter. The air temperature was computed using maximum-minimum thermometers, RH with dry and wet bulb thermometers, each installed under different structures and observations were recorded on daily basis. All of the data were statistically analyzed according to Panse and Sukhatme, 1985.

RESULT AND DISCUSSION

Information regarding various growth parameters *viz.*, days taken for germination, seedling height, seedling diameter, number of leaves, survival percentage and leaf photosynthesis of papaya seedling under different shade net colours *i.e.* red, white,

green, blue, yellow and open condition are presented in Table 1.

Effect of different colour shade nets on growth parameters

The result revealed that the effect of different colour shade nets on growth parameters of papaya was found significant with respect to days taken for germination, survival (%), seedling height (cm), seedling diameter (mm) and number of leaves per seedling. The results presented in Table 1 reflected that earlier germination (16.21) and highest survival (60.00%) were noted in T₂ (white colour) treatment in pooled analysis which was at par with T₃ (green colour) treatment. The lower shading intensity that provide more light flux reaching to the absorbing parts and selectivity of absorption of photosynthetically active radiation and thus taken less day for germination with more success rate (Serat and Kulkarni, 2013). Conversely, the lower survival percentage in the yellow shade net and other shade net colors may be attributed to their opaque nature, resulting in reduced reflection across all light spectra. This phenomenon lower down the photosynthetic activity resulted in less germination and survival percentage.

During periodical observations at 30 DAS and 45 DAS, the maximum seedling height (6.13 cm and 11.75 cm, respectively), seedling diameter (1.20 mm and 2.32, respectively) and number of leaves per seedlings (6.27 and 8.69, respectively) were noted in T₂ (white colour) treatment during. For seedling diameter at 30 DAS, the treatment T₂ was at par with T₃.

Smith (1982) reported that the incremental in plant height under white shade net could be attributed to the shade avoidance that induced by lower PAR light (Table 2). However, the elongation may be linked to an extreme reduction in incident radiation and PAR due to the density of the shade net. Among the various treatments, the growth parameters

were most pronounced in the 50% white colour structure, where increased reflectance and interception of light might have influenced elevated temperatures, consequently resulting in greater diameter. Previous research has demonstrated that shading increases carbohydrate accumulation in leaves (Raveh *et al.*, 2003) and also due to favourable microclimatic condition under the white colour which could induced the higher vegetative growth as compared to open condition. This aligns with findings from Incesu *et al.* (2016), who noted comparable leaf numbers in 'Lane Late' Navel orange trees grown under a 13% clear shade net when compared to those in the control treatment.

Effect of different colour shade nets on photosynthesis of papaya

In case of photosynthesis rate, the mean results are presented in Table 1. Irrespective of the papaya seedlings, significantly higher values of photosynthesis rate ($468.40 \mu\text{mol CO}_2\text{m}^{-2}\text{s}^{-1}$) at 45 DAS was observed in T₂ (white colour) which was at par with T₃ treatment. As the photosynthesis rate has direct effect on seedling growth of papaya so from all treatments, white colour has maximum plant success than all other shade nets. Under open field condition, lower rate of photosynthesis was attributed to the phenomenon of light saturation (at this point increase in light intensity did not cause increases in photosynthesis rate, so other factors apart from the supply of light must be limiting the photosynthetic process). Gaurav *et al.*, (2016) reported that chlorophyll content and photosynthetic rates were higher under white shade nets due to higher transpiration rate and gaseous exchange occur in plants.

Effect of different colour shade nets on weather parameters of papaya

The respective data are presented in Table 2 to 4 on standard meteorological week basis.

The study was carried out during summer season (March-April month) only 11th to 16th standard meteorological week data are presented.

Light intensity

The light was recorded at 15 minute interval starting from 9:00 hrs up to 17.00 hrs consecutively for entire period (twice in a week) and the average values are presented in Table 2. The light intensity slowly increased and reached peak at 12.30 hrs then decreased slowly up to 17.00 hrs in all surroundings. The mean data on light intensity was recorded higher in open field ($695.5 \mu\text{mol m}^{-2}\text{s}^{-1}$) compare to all shade nets whereas lower values observed in white colour ($320.1 \mu\text{mol m}^{-2}\text{s}^{-1}$) shade net condition. This phenomenon arises from the distinctive characteristics of various color shade nets, where different colors reduce transmittance without scattering light, while white shade nets both reduce transmittance and effectively scatter light, as outlined by Selahle *et al.*, 2014. Additionally, the observed effects could be attributed to energy conversion into heat, influencing processes like photosynthesis and transpiration. This energy plays a role in determining tissue temperatures, thereby impacting the rates of metabolic processes and balance among it (Jones 1992). It also might be due to lower light intensity, lower canopy temperature and higher RH under different coloured shade nets (Smith *et al.*, 1984).

Temperature

Regarding temperatures, mean minimum-maximum weekly temperature under the different shade net structure and open condition are mentioned in Table 3. The cooling effect was observed under white colour shade net which was about 3°C less during all individual years of experiment as compared to open condition. The impact of shade nets on temperature, characterized by a reduction across all seasons and the highest humidity in

winter, is likely attributed to the diverse colors of the shade nets. It is essential to acknowledge that these environmental conditions can directly influence plant growth and phytochemistry. Reduced temperatures, for instance, may alleviate stress and photoinhibition, potentially enhancing resource use efficiency (Arthurs *et al.*, 2013; Stamps, 2009). Additionally, elevated relative humidity plays a role in decreasing the vapor pressure deficit, thereby promoting stomatal conductivity and enhancing the rate of photosynthesis (Mortensen and Gislerod, 1999).

Relative humidity (%)

The standard week RH values are the average of daily RH values. Overall, the RH values recorded inside shade net houses are higher than that observed in control this may

be attributed to 50 per cent shading effect. Here, under red, white, blue and green colour shade nets recorded relatively higher RH per cent than yellow colour shade and open condition. Average relative humidity increased in white shade net treatment by 6-9% as compared to control (Table 4). These results were in line with those reported by Iglesias and Alegre, (2006) indicating a 2-6% increase in humidity due to different nets. They also observed a reduction in evaporation associated with use of nets and a significant reduction in wind speed.

Disease and pest:

During all the three years of experiments, there were fewer incidences of pest and disease were detected, but it was not found above the economic threshold level.

Table 1: Effect of different colour shade nets on different growth parameters and photosynthesis papaya var. GJP-1

Treatments	Days taken for germination	Survival (%)	Seedling height (cm)		Seedling diameter (mm)		No. of leaves per seedling		Photosynthesis ($\mu\text{mol CO}_2\text{m}^{-2}\text{s}^{-1}$)
			30DAS	45DAS	30DAS	45DAS	30DAS	45DAS	
T ₁ = Red colour	17.64	51.56	5.59	9.92	1.11	1.78	5.90	7.43	459.60
T ₂ = White colour	16.21	60.00	6.13	11.75	1.20	2.32	6.27	8.69	468.40
T ₃ = Green colour	17.37	57.33	5.93	11.01	1.18	2.20	6.03	8.05	463.20
T ₄ = Blue colour	18.19	47.89	5.00	8.79	0.91	1.64	5.72	6.66	459.07
T ₅ = Yellow colour	18.02	46.67	5.20	8.29	0.96	1.65	5.18	7.27	454.67
T ₆ = Control	21.71	28.33	3.67	5.88	0.80	1.52	4.93	6.45	448.94
S.Em. $\pm$	0.41	1.12	0.05	0.10	0.02	0.06	0.08	0.25	3.06
C.D. at 5%	1.18	3.23	0.16	0.28	0.05	0.20	0.22	0.79	8.99
Y x T									
S.Em. $\pm$	0.72	1.95	0.09	0.17	0.03	0.04	0.13	0.24	4.32
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V. %	6.81	6.94	3.10	3.18	4.81	3.42	4.04	5.68	1.63

Table 2: Data on PAR radiation ($\mu\text{mol m}^{-2}\text{s}^{-1}$) under different colour shade nets and open field

Light Intensity-Average						
Time	Red	White	Green	Blue	Yellow	Open
09.00	151.5	186.6	151.1	167.6	142.9	241.5
09.15	186.2	220.5	201.9	196.9	162.5	299.6
09.30	215.0	242.6	231.4	233.4	217.0	331.0
09.45	250.9	261.5	262.9	261.7	250.0	409.1
10.00	282.3	288.7	292.2	291.6	284.1	444.2
10.15	327.9	304.8	318.4	328.3	332.0	569.5
10.30	376.5	326.7	357.8	369.4	361.7	680.4
10.45	421.5	355.1	394.0	405.8	426.2	810.2
11.00	460.2	395.7	406.9	454.3	456.0	880.1
11.15	483.8	417.8	451.0	493.9	479.6	924.8
11.30	514.1	434.8	453.3	515.5	500.2	982.4
11.45	537.0	467.3	486.4	531.6	533.8	1001.3
12.00	563.1	471.1	508.9	564.7	554.8	1024.2
12.15	581.4	511.4	533.6	573.9	565.1	1081.4
12.30	597.6	526.6	569.1	591.8	588.0	1096.3
12.45	550.8	471.5	473.5	545.1	500.2	1028.6
13.00	477.1	463.0	450.0	474.1	419.9	1026.9
13.15	441.3	442.8	426.4	429.4	381.2	1018.2
13.30	396.1	424.8	406.9	400.0	369.1	978.2
13.45	367.2	396.5	396.4	379.0	363.3	961.5
14.00	338.0	357.5	373.0	344.7	354.0	936.3
14.15	310.0	321.5	336.5	318.0	347.6	897.6
14.30	294.3	301.5	319.9	299.7	350.2	847.5
14.45	256.0	283.3	289.4	260.3	319.2	818.4
15.00	235.4	264.7	276.3	249.5	311.1	761.0
15.15	219.7	242.3	250.2	229.1	283.4	709.9
15.30	200.3	229.2	236.1	214.6	262.8	596.4
15.45	174.0	218.2	223.7	196.3	239.5	455.9
16.00	158.9	193.6	205.2	177.5	213.2	367.6
16.15	136.0	169.7	194.6	164.2	190.9	270.7
16.30	129.5	145.7	185.5	140.4	167.3	196.4
16.45	121.3	125.1	156.6	118.3	145.2	160.5
17.00	104.0	100.4	134.1	106.0	134.7	143.3
Mean	329.1	320.1	331.9	334.1	339.6	695.5

Table 3: Data on Maximum-minimum temperature (°C) under different colour shade nets and open field

	Average												
Treatment / Duration		Red		White		Green	Blue		Yellow		Open field		
Week No.	Date	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
11	12 March- 18 March	35.9	22.4	34.6	20.4	37.0	22.6	34.9	22.0	35.5	24.5	37.7	25.5
12	19 March- 25 March	35.6	20.7	35.3	21.9	37.6	23.6	38.2	23.7	38.2	24.2	38.3	26.1
13	26 March- 01 April	37.6	23.4	36.2	22.2	39.0	22.8	35.4	23.5	38.1	24.4	39.2	27.0
14	02 April - 08 April	35.9	22.3	36.6	22.6	36.2	21.6	35.4	26.0	37.7	24.0	38.6	23.8
15	09 April- 15 April	35.1	24.8	35.1	23.2	36.2	22.3	35.0	24.1	36.6	24.7	38.0	24.3
16	16 April- 22 April	34.1	22.7	35.3	22.0	35.1	24.5	33.2	21.9	36.5	24.8	37.9	26.1

Table 4: Data on humidity (%) under different colour shade nets and open field

Treatment/Duration	Average humidity (%)					
	Red	White	Green	Blue	Yellow	Open field
Week No. 11: 12 March- 18 March	84.3	81.5	83.3	81.1	78.8	73.9
Week No. 12: 19 March- 25 March	87.3	85.8	80.6	90.8	81.3	75.3
Week No. 13: 26 March- 01 April	88.2	76.4	81.2	85.7	83.5	78.1
Week No. 14: 02 April - 08 April	84.1	86.5	92.1	90.2	80.7	75.2
Week No. 15: 09 April- 15 April	90.0	80.6	83.3	91.8	76.8	78.2
Week No. 16: 16 April- 22 April	87.7	84.7	91.2	90.0	84.2	81.3

CONCLUSION

From foregoing discussion, it can be accomplished that for early germination and higher seedling growth were obtained when papaya seeds sown under 50 per cent white shade net structure.

REFERENCE

- Aravind, G.; Bhowmik, D.; Duraival, S. and Harish, G. (2013). Traditional and medicinal uses of *Carica papaya*. *J. Medicinal Plant Stud.*, 1(1): 7-15.
- Arthurs, S. P.; Stamps, R. H. and Giglia, F. F. (2013). Environmental modification inside photoselective shadehouses. *Hort. Sci.*, 48(8): 975-979.
- Azad, M. A. K.; Rabbani, M. G. and Amin, L. (2012). Plant regeneration and somatic embryogenesis from immature embryos derived through interspecific hybridization among *Carica* sp. *Int. J. Molecular Sci.*, 13: 17065-17076.
- Gaurav, A. K.; Raju, D. V.; Janakiram, T.; Singh, B.; Jain, R. and Krishnan, S. G. (2016). Effect of different coloured shade nets on production and quality of cordyline. *Indian J. Agric. Sci.*, 86(7): 865-869.
- Iglesias, I. and Alegre, S. (2006). The effect of anti-hail nets on fruit protection, radiation, temperature, quality and profitability of Mondial Gala apples. *J. Applied Hort.*, 8(2): 91-100.
- Incesu, M.; Yesiloglu, T.; Cimen, B. and Yilmaz, B. (2016). Effects of nursery shading on plant growth, chlorophyll content and PS II in Lane Late Navel orange seedlings. *Acta Hort.*, 1130: 301-306.
- Jones, H. G. (1992). Plants and Microclimate: A Quantitative Approach to Environmental Plant Physiology. *Cambridge University Press, Cambridge*.
- Lamont, G. P. and O'Connell, M. A. (1987). Shelf life of bedding plants as influenced by potting media and hydrogels. *Scientia Hort.*, 31: 141-149.
- Mortensen, L. M. and Gislerod, H. R., (1999). Influence of air humidity and lighting period on growth, vase life and water relations of 14 rose cultivars. *Scientia Hort.*, 82(3-4): 289-298.
- Oren-Shamir, M.; Gussakovsky, E.; Shpiegel, E.; Nissim-Levi, A. Ratner, K.; Ovadia, R. Giller, Y. and Shahak, Y. (2001). Coloured shade nets can improve the yield and quality of green decorative branches of *Pittosporum variegatum*. *J. Hort. Sci. and Biotech.*, 76: 353-361.
- Panse, V. G. and Sukhatme, P. V. (1985). *Statistical methods for agricultural workers*, ICAR: New Delhi. pp. 152-165.

12. Popenoe, W. (1974). Manual of Tropical and Subtropical Fruits", *Hafner Press*, PP. 225-269.
13. Raveh, E.; Cohen, S.; Raz, T.; Yakir, D.; Grava, A. and Goldschmidt, E. E. (2003). Increased growth of young citrus trees under reduced radiation load in a semi-arid climate. *J. Exp. Bot.*, **54**: 365-373.
14. Selahle, M. K.; Sivakumar, D. and Soundy, P. (2014). Effect of photo-selective nettings on post harvest quality and bioactive compounds in selected tomato cultivars. *J. Sci. Food and Agric.*, **94**(11): 2187-2195.
15. Serat, B. and Kulkarni, S. S. (2013). Effect of shade net on yield and quality of grapes cv. Thompson Seedless. *Int. J. Sci. and Res.*, **6**: 1841-1844.
16. Shahak, Y.; Gussakovsky, E.; Gal, E. and Ganelevin, R. (2004). Colour nets: crop protection and light-quality manipulation in one technology. *Acta Hort.*, **659**: 143-151.
17. Smith, H. (1982). Light quality, photoperception and plant strategy. *Annual Review Plant Physio.*, **33**: 481-518.
18. Smith, I. E.; Savage, M. J. and Mills, P. (1984). Shading effects on greenhouse tomatoes and cucumbers. *Acta Hort.*, **148**: 491-500.
19. Stamps, R. H. (2009). Use of colored shade netting in horticulture. *Hort. Sci.*, **44**(2): 239-241.



EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH OF ONION (*ALLIUM CEPA* L.)

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ABSTRACT

The present investigation took place during the *rabi* season of 2021-22 and 2022-23 at the Experimental Farm, Department of Agriculture, School of Sciences and Agriculture located in Kasmabad, Monad University, Hapur, Uttar Pradesh. In the present investigation the design used for analysis of variables were Randomized Block Design (RBD) comprising 3 replications sixteen treatment combinations. The details of treatments comprised of T₁ Control (water spray), T₂ (100% RDF [NPK- 120:60:60 kg/ha]), T₃ (75% RDF + 6.0 t/ha FYM), T₄ (75% RDF + 1.0 t/ha PM), T₅ (75% RDF + 2.0 t/ha VC), T₆ (75% RDF + 3.0 t/ha FYM + 0.5 t/ha PM), T₇ (75% RDF + 1.0 t/ha VC + 0.5 t/ha PM), T₈ (75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)), T₉ (75% RDF + 1.0 t/ha PM + Azotobacter (4 kg/ha)), T₁₀ (75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)), T₁₁ (50% RDF + 12.0 t/ha FYM), T₁₂ (50% RDF + 2.0 t/ha PM), T₁₃ (50% RDF + 4.0 t/ha VC), T₁₄ (50% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)), T₁₅ (50% RDF + 2.0 t/ha PM + Azotobacter (4 kg/ha)) and T₁₆ (50% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)). From the above experimental finding it is concluded that the treatment T₈ (75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)) was found to be best in the terms of growth, and earliness in maturity of Onion evaluated for different doses of organic and inorganic fertilizers integrated together.

Keywords: *Allium cepa*, Farmyard Manure, Vermicompost, Benefit cost ratio.

INTRODUCTION

Because of its nutritional and flavouring qualities, onions are a commercially significant bulb crop that are consumed by both vegetarians and non-vegetarians. The properties of onions include stimulant, diuretic, expectorant, and antibacterial effects. By reducing blood cholesterol and lipid levels, it prevents heart disease (14).

Botanically known as *Allium cepa* (L.), belongs to family Amaryllidaceae having garlic, scallion, leek, and chive close relative (1). Other species in this genus that are grown for food and are also referred to as onions include the tree onion *Allium ×proliferum*, the Canada onion *Allium canadense*, and the Japanese bunching onion *Allium fistulosum*. Many *Allium* species are referred to as “wild

onions,” however only *A. cepa* is known from cultivation. Although escapes from cultivation have become established in some areas, its ancestral wild form is unknown (10). Onion bears chromosome number $2n=16$ (5). There is little historical record of the ancestors of onion species. The geographic origin of the onion is unknown because historical records of its use span both western and eastern Asia. However, domestication—which has been variously attributed to Iran, western Pakistan, and Central Asia—most likely occurred in West or Central Asia (3). Although onions are typically grown as annuals and harvested during their first growing season, they are actually most often biennial or perennial plants. The bulb at the base of the onion plant swells when a specific day length is attained. The onion plant has a fan of hollow, bluish-green leaves. The bulbs are made up of compressed, shortened underground stems that have a central bud at the tip and are encircled by fleshy modified scales, or leaves. In the year 2021-22, Onion production in India covered an area of 5.36 million hectares, yielding a total production of 31.28 million tonnes, according to data from the Department of Economics and Statistics (DES), Ministry of Agriculture & Farmers Welfare, Government of India. Maharashtra emerged as the leading state in both the area and production of onion in the year 2021-22, followed by Madhya Pradesh, Karnataka, and Gujarat. In Uttar Pradesh, the onion production area amounted to 0.21 million hectares, resulting in a production of 5.08 million tonnes for the same year. Although onions are a temperate crop, they can be grown in a variety of climates, including tropical, subtropical, and temperate. The ideal results can be achieved in moderate weather that avoids extremes of heat, cold, and precipitation. Through biological breakdown, farmyard manure provides nitrogen, phosphorus, potassium, and other essential nutrients to plants in an accessible form. It enhances the organic matter content,

microbial activity, aggregation, aeration, water-holding capacity, and available nutrients, among other physical, chemical, and biological aspects of soil. Worm casting, organic materials, and living earthworms are combined to create vermicompost. It is organic manure that releases nutrients gradually and contains the majority of the macro and micronutrients needed by plants (8). On average, well-decomposed farmyard manure contains approximately 0.5% Nitrogen (N), 0.2% Phosphate (P_2O_5), and 0.5% Potassium (K_2O). Additionally, FYM enhances the availability of soil phosphorus. Furthermore, when FYM is used in conjunction with fertilizer phosphorus, it can impact the solubility and potential availability of applied phosphorus. It's essential to recognize that neither the sole use of organic manure nor chemical fertilizers in isolation can ensure sustainable and productive yields in modern intensive farming. A balanced approach that combines both organic and chemical inputs is often necessary to achieve long-term agricultural sustainability (Singh and Singh, 2018). In recent times, developing nations' governments have aimed to encourage a shift in production and exports, moving away from traditional commodities. This strategy is intended to expedite economic growth, widen job opportunities, and diminish rural poverty (7). Embracing market-driven production enables households to augment their earnings by producing goods that yield greater returns concerning land and labour. This income, generated from sales, is then used to acquire goods for consumption. Consequently, the cultivation of vegetable crops has experienced swifter growth compared to cereal crops (9). In these developing nations, vegetable crops hold notable significance in both economic and social aspects, aiding in the enhancement of income levels and nutritional standards. Farmers engaged in vegetable cultivation typically earn substantially higher incomes in

comparison to those focusing on cereals, with reported farm incomes per capita reaching up to five times higher. Moreover, horticultural products serve as income-boosting alternatives for small-scale farmers in place of staple grains, contributing significantly to heightened employment opportunities. In contemporary agriculture, reducing reliance on chemical fertilisers and promoting sustainable production are critical concerns that can only be addressed by an integrated plant nutrient supply system (IPNS). Therefore, the potential yield increases with the amount of nutrients it can use to produce crops. In order to investigate the various inorganic, organics, and bio-organic treatment combinations, the current experiments was undertaken to find out the effect of inorganic fertilizers and bio-organics on growth of onion and to find out the suitable dose of inorganic fertilizers and sources of organic manures and bio-inoculants.

MATERIALS AND METHODS

The present investigation took place during the *rabi* season of 2021-22 and 2022-23 at the Experimental Farm, Department of Agriculture, School of Sciences and Agriculture located in Kasmabad, Monad University, Hapur, Uttar Pradesh. Geographically, Hapur, situated in Uttar Pradesh, India, functions as both the city and the administrative headquarters of the Hapur district. Positioned approximately 60 kilometres to the east of New Delhi, this city is an integral part of the Delhi National Capital Region (NCR). Hapur is positioned at an average elevation of 213 meters above mean sea level, situated between coordinates 77°78" E longitude and 28°72" N latitude. This region falls under Agroclimatic Zone V (Upper Gangetic Plain Region). The experimental site's topography is primarily flat, with soil composition characterized by sandy loam. The soil, reaching a depth of 0-30 cm, was

systematically sampled, and subjected to thorough analysis to evaluate multiple parameters. The soil pH was 7.06 (measured by digital pH meter); organic carbon content was found to be 0.52% (measured by wet method, Walkely and Black, 1965). The **Fisher and Yates, 1963** method was used to statistically analyse the data. The software used for analysis was INDOSTAT. The onion variety used was Agrifound light red. In the study, the height of randomly chosen plants from each plot was assessed in centimetres using a meter scale. Additionally, the number of leaves per plant, emerging from the main shoot, was counted, and the values were averaged. Neck thickness was also measured using measuring tape. All observations were recorded at 30, 60, 90 DAT. The days taken in maturing of bulb from days after transplanting was counted and recorded as days taken to maturity of bulb of onions in each replication and treatments. In the present investigation the design used for analysis of variables were Randomized Block Design (RBD) comprising 3 replications sixteen treatment combinations. The details of treatments comprised of T₁ Control (water spray), T₂ (100% RDF [NPK- 120:60:60 kg/ha]), T₃ (75% RDF + 6.0 t/ha FYM), T₄ (75% RDF + 1.0 t/ha PM), T₅ (75% RDF + 2.0 t/ha VC), T₆ (75% RDF + 3.0 t/ha FYM + 0.5 t/ha PM), T₇ (75% RDF + 1.0 t/ha VC + 0.5 t/ha PM), T₈ [75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)], T₉ [75% RDF + 1.0 t/ha PM + Azotobacter (4 kg/ha)], T₁₀ (75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)), T₁₁ (50% RDF + 12.0 t/ha FYM), T₁₂ (50% RDF + 2.0 t/ha PM), T₁₃ (50% RDF + 4.0 t/ha VC), T₁₄ [50% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)], T₁₅ [50% RDF + 2.0 t/ha PM + Azotobacter (4 kg/ha)] and T₁₆ (50% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)).

RESULTS AND DISCUSSION

The data pertaining to the plant's height

varied significantly depending on the combination of treatments for *rabi* season 2021-22. At 30, 60 and 90 DAT, treatment T₈ (75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)) produced the highest plant height (32.41, 57.92, 70.22 cm respectively), which was followed by treatment T₁₀ (75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha) with 29.82, 54.26, 66.46 cm respectively. T₁ (control) showed the minimum plant height of 20.20, 35.29, 52.21 cm respectively, whereas the growth habits of the other treatments were moderate. The information about the plant's height changed dramatically based on the combination of treatments used during the 2022–2023 *rabi* season. The highest plant height (36.42, 60.51, 73.19 cm) was achieved at 30, 60 and 90 DAT respectively by treatment T₈ (75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)), which was followed by treatment T₁₀ (75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha) with 33.57, 56.15, 70.95 cm respectively. The minimum plant height of T₁ (control) was recorded at 23.75, 39.21, 52.59 cm respectively, while the other treatments exhibited moderate growth habits. Similar pattern was also revealed by pooled mean analysis. The interaction effect can be disregarded because it has been found to be significant but is small in comparison to the average effect, which means that the treatment ranking should remain stable year over year. Depending on the combination of treatments used for pooled mean, the plant's height data varied significantly. The plants that were tallest at 30, 60 and 90 DAT were treated T₈ (75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)), with a height of 34.42, 59.21, 67.41 cm respectively. Treatment T₁₀ (75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)) produced plants that were tallest at 31.70, 55.20, 68.70 cm respectively. While the growth habits of the other treatments were moderate, T₁ (control) displayed the minimum plant height of 21.97, 37.30, 52.29 cm at 30, 60 and 90 DAT respectively. The data is depicted

in table 1 and 2 The treatment combination of 75% recommended dose of fertilizer (RDF), 6.0 t/ha farmyard manure (FYM), and Azotobacter (4 kg/ha) has remarkably bolstered onion plant height compared to other treatments, notably the control group. This synergy addresses multiple growth facets: the 75% RDF offers vital macro and micronutrients, fortifying plant development; the 6.0 t/ha FYM enriches soil with organic matter, augmenting nutrient retention and microbial activity essential for sustained growth; and Azotobacter, a nitrogen-fixing bacterium, enhances nutrient availability by converting atmospheric nitrogen into a usable form, fostering robust growth. This holistic approach optimizes soil fertility, ensuring balanced nutrient uptake, improved root development, and overall plant vigour, resulting in notably superior onion plant height in this treatment combination compared to alternative methods, including the control. Similar results were concluded by (22, 4, and 19).

For the 2021–2022 *rabi* season, the data regarding the number of leaves per plant varied significantly based on the combination of treatments. The treatment with the greatest number of leaves per plant at 30, 60 and 90 DAT was T₈ (75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)), with 7.18, 9.36 and 12.79 leaves respectively. Treatment T₁₀ (75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)) produced 6.90, 9.25 and 14.61 leaves respectively and at par with T₈. While T₁ (control) displayed the bare minimum of 4.11, 5.44 and 7.97 leaves per plant respectively at 30, 60 and 90 DAT. The combination of treatments applied during the 2022–2023 *rabi* season caused a minor shift in the data regarding the number of leaves per plant. Treatment T₈ (75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)) produced the greatest number of leaves per plant (8.06, 10.28 and 15.31 leaves) at 30, 60 and 90 DAT at par with

T₁₀ (75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)) producing the second-highest number of leaves (7.77, 9.96 and 14.61 leaves). The T₁ (control) treatment showed a minimum of 4.89, 6.27 and 8.62 leaves per plant at 30, 60 and 90 DAT respectively. Pooled mean analysis also showed a similar pattern. Since the interaction effect is small compared to the average effect and has been found to be significant, it can be ignored, meaning that the treatment ranking should not change from year to year. The number of leaves per plant data for pooled mean varied significantly depending on the combination of treatments used. At 30, 60 and 90 DAT respectively, highest number of leaves (7.62, 9.82 and 14.05) was observed in T₈ (75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)) significantly at par with T₁₀ (75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)) measuring 7.34, 9.61 and 13.52 leaves. T₁ (control) showed the least number of leaves (4.50, 5.85 and 7.97). The data is depicted in table 2 and 3. The treatment combination of 75% recommended dose of fertilizer (RDF), 6.0 t/ha farmyard manure (FYM), and Azotobacter (4 kg/ha) demonstrates a notable increase in the number of leaves in onions in comparison to other treatments, notably the control group. This effect is attributed to a multi-faceted synergy within this combination: the 75% RDF supplies crucial nutrients, supporting leaf formation and growth; the 6.0 t/ha FYM enriches the soil with organic matter, enhancing nutrient retention and fostering an environment conducive to increased leaf production. Azotobacter, known for nitrogen fixation, augments nutrient availability by converting atmospheric nitrogen into a usable form, stimulating robust leaf development. This combined approach optimizes soil fertility, ensures a balanced nutrient supply, and promotes a healthier root system, ultimately resulting in a significantly higher number of leaves in the onion plants compared to alternative treatments, notably the control

group. (15, 12 and 19) came to similar conclusions.

The information regarding the neck thickness of each plant indicated that, depending on the combination of treatments used for the *rabi* season 2021–2022, there were significant differences between treatments. The treatment with the maximum neck thickness (2.32, 2.75 cm) at 60 and 90 days after transplanting was T₈ (75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)) at par with T₁₀ (75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)), with 2.24 and 2.58 cm at 30 and 90 days after transplanting respectively. T₁ (control) had the minimum neck thickness, with an average of 1.10, 1.09 cm respectively. The data on the neck thickness experienced a slight shift as a result of the combination of treatments used during the 2022–2023 *rabi* season. Treatment T₈ (75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)) produced the greatest neck thickness (2.65 and 3.45 cm) at 60 DAT at par with T₁₀ (75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)) producing the second-highest number of cm (2.57, 3.28 cm). The T₁ (control) treatment showed a lowest of neck thickness with 1.43, 1.79 cm. Pooled mean analysis also showed a similar pattern. Since the interaction effect is small compared to the average effect and has been found to be significant, it can be ignored, meaning that the treatment ranking should not change from year to year. The neck thickness data for pooled mean varied significantly depending on the combination of treatments used. At 60 and 90 DAT, highest neck thickness (2.48, 3.10 cm) was observed in T₈ (75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)) significantly at par with T₁₀ (75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)) measuring 2.41, 2.93 cm. T₁ (control) showed the lowest neck thickness (1.26, 1.44 cm). The data is depicted in table 4. Onion neck thickness is significantly higher in the treatment combination of 75% recommended dose of fertiliser (RDF), 6.0 t/ha farmyard

manure (FYM), and Azotobacter (4 kg/ha) than in the other treatments, especially the control group. This effect results from the combination's complete synergy: the 6.0 t/ha FYM enriches the soil with organic matter, enhancing soil structure and nutrient availability that are critical for enhanced bulb development, including neck thickness; the 75% RDF provides essential nutrients necessary for bulb development, contributing to thicker neck formation. The nitrogen-fixing capacity of Azotobacter increases the uptake of nutrients, particularly nitrogen, which promotes robust growth of the bulb and neck. When compared to other methods, this holistic approach produces onions with a noticeably thicker neck because it maximises soil fertility, nutrient uptake, and bulb development. Similar conclusions were reached by **Adia *et al.*, (2018), (11) and (13).**

The days taken to maturity data showed that there were significant differences in treatment combinations for the 2021–2022 *Rabi* season. T₈ (75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)) reported early most in terms of maturity (84.79 days). This was followed by T₁₀ (75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)), which had 86.96 days. With an average of 110.77 days, T₁ (control) had the delayed maturity. The combination of treatments applied during the 2022–2023 *rabi* season caused a slight shift in the data on days taken to maturity. When compared to treatment T₁₀ (75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)), which produced the second-most earliness in maturity (86.90 days), treatment T₈ (75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)) produced the early most duration in maturity (90.18 days). The maximum days taken to maturity 115.92 days in the T₁ (control) treatment. A similar pattern was also revealed by pooled mean analysis. The interaction effect can be disregarded

because it is not statistically significant and is small in comparison to the average effect. This implies that the treatment ranking should remain constant from year to year. Depending on the mix of treatments applied, the days taken to maturity data for pooled mean analysis varied significantly. T₈ (75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)) took minimum duration for maturity (85.85 days), which was considerably equal to T₁₀ (75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)), with 88.57 days. T₁ (control) exhibited the maximum duration taken for maturity (113.34 days). The data is depicted in table 5. The treatment combination of 75% recommended dose of fertilizer (RDF), 6.0 t/ha farmyard manure (FYM), and Azotobacter (4 kg/ha) accelerates onion bulb maturity compared to other treatments, notably the control. This synergy expedites maturity due to several factors: the balanced nutrient supply from RDF enhances plant growth, while FYM enriches soil with organic matter, promoting early root development crucial for quicker maturity. Azotobacter's nitrogen fixation further fuels growth, hastening the bulb's development cycle. Collectively, this combination optimizes nutrient availability and root establishment, culminating in earlier onion bulb maturity compared to alternative treatments, notably the control group. Conclusions were in accordance with works of **Yadav *et al.*, (2020).**

Conclusion

From the above experimental finding it is concluded that the treatment T₈ (75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)) was found to be best in the terms of growth, and earliness of Onion evaluated for different doses of organic and inorganic fertilizers integrated together.

Table 1 Effect of integrated nutrient management on plant height of Onion.

Plant height (cm)							
		30 Days after transplanting			60 Days after transplanting		
Treatment Notation	Treatment Details	2021	2022	Pooled Mean	2021	2022	Pooled Mean
T ₁	Control	20.20	23.75	21.97	35.39	39.21	37.30
T ₂	100% RDF [NPK- 120:60:60 kg/ha]	21.99	25.61	23.80	41.75	42.37	42.06
T ₃	75% RDF + 6.0 t/ha FYM	23.68	27.35	25.51	43.66	45.90	44.78
T ₄	75% RDF + 1.0 t/ha PM	23.26	26.92	25.09	42.96	45.16	44.06
T ₅	75% RDF + 2.0 t/ha VC	23.44	27.11	25.28	41.48	45.44	43.46
T ₆	75% RDF + 3.0 t/ha FYM + 0.5 t/ha PM	25.29	29.02	27.15	47.36	49.03	48.20
T ₇	75% RDF + 1.0 t/ha VC + 0.5 t/ha PM	24.63	28.35	26.49	44.07	46.07	45.07
T ₈	75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)	32.41	36.42	34.42	57.92	60.51	59.21
T ₉	75% RDF + 1.0 t/ha PM + Azotobacter (4 kg/ha)	28.73	32.44	30.58	52.30	54.12	53.21
T ₁₀	75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)	29.82	33.57	31.70	54.26	56.15	55.20
T ₁₁	50% RDF + 12.0 t/ha FYM	26.22	29.83	28.02	44.01	49.45	46.73
T ₁₂	50% RDF + 2.0 t/ha PM	25.34	28.92	27.13	44.76	47.46	46.11
T ₁₃	50% RDF + 4.0 t/ha VC	26.65	30.29	28.47	46.77	50.20	48.49
T ₁₄	50% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)	28.51	32.21	30.36	49.11	52.05	50.58
T ₁₅	50% RDF + 2.0 t/ha PM + Azotobacter (4 kg/ha)	26.76	30.40	28.58	45.45	48.89	47.17
T ₁₆	50% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)	27.80	31.47	29.63	46.75	50.76	48.76
F' Test	S	S	S	S	S	S	
CD _{0.05}	0.24	0.31	0.34	2.42	1.31	2.09	
SE. m (±)	0.08	0.10	0.11	0.78	0.42	0.69	
CV. (%)	5.52	4.18	0.46	2.92	1.08	1.38	

Table 2 Effect of integrated nutrient management on plant height and number of leaves per plant of Onion.

Treatment Notation	Treatment Details	Plant height (cm) 90 DAT			No of leaves 30 DAT		
		2021	2022	Pooled Mean	2021	2022	Pooled Mean
T ₁	Control	52.21	52.96	52.59	4.11	4.89	4.50
T ₂	100% RDF [NPK- 120:60:60 kg/ha]	56.39	57.63	57.01	4.45	5.24	4.85
T ₃	75% RDF + 6.0 t/ha FYM	60.75	62.01	61.38	4.28	5.07	4.68
T ₄	75% RDF + 1.0 t/ha PM	58.47	60.61	59.54	4.33	5.13	4.73
T ₅	75% RDF + 2.0 t/ha VC	55.92	61.40	58.66	3.98	4.76	4.37
T ₆	75% RDF + 3.0 t/ha FYM + 0.5 t/ha PM	63.57	66.22	64.90	4.37	5.18	4.78
T ₇	75% RDF + 1.0 t/ha VC + 0.5 t/ha PM	55.76	58.29	57.02	5.12	5.93	5.53
T ₈	75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)	70.22	73.19	71.71	7.18	8.06	7.62
T ₉	75% RDF + 1.0 t/ha PM + Azotobacter (4 kg/ha)	66.39	68.43	67.41	6.20	7.05	6.62
T ₁₀	75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)	66.46	70.95	68.70	6.90	7.77	7.34
T ₁₁	50% RDF + 12.0 t/ha FYM	58.02	62.65	60.33	5.77	6.60	6.19
T ₁₂	50% RDF + 2.0 t/ha PM	58.33	60.54	59.44	5.56	6.40	5.98
T ₁₃	50% RDF + 4.0 t/ha VC	62.81	63.02	62.92	5.60	6.43	6.02
T ₁₄	50% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)	63.25	65.03	64.14	6.99	7.15	7.07
T ₁₅	50% RDF + 2.0 t/ha PM + Azotobacter (4 kg/ha)	59.95	61.44	60.69	6.70	6.87	6.79
T ₁₆	50% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)	62.40	63.76	63.08	6.61	7.14	6.87
F' Test	S	S	S	S	S	S	
CD _{0.05}	2.61	1.59	2.25	0.81	0.29	0.73	
SE. m (±)	0.84	0.51	0.75	0.26	0.09	0.24	
CV. (%)	2.39	1.31	1.19	8.14	2.62	3.47	

Table 3 Effect of integrated nutrient management on number of leaves per plant of Onion.

No of leaves per plant							
		60 Days after transplanting			90 Days after transplanting		
Treatment Notation	Treatment Details	2021	2022	Pooled Mean	2021	2022	Pooled Mean
T ₁	Control	5.44	6.27	5.85	7.33	8.62	7.97
T ₂	100% RDF [NPK- 120:60:60 kg/ha]	6.58	7.24	6.91	8.24	10.12	9.18
T ₃	75% RDF + 6.0 t/ha FYM	6.37	7.06	6.71	8.25	9.91	9.08
T ₄	75% RDF + 1.0 t/ha PM	6.54	7.11	6.83	8.40	9.97	9.19
T ₅	75% RDF + 2.0 t/ha VC	6.19	6.72	6.45	8.88	10.78	9.83
T ₆	75% RDF + 3.0 t/ha FYM + 0.5 t/ha PM	6.49	7.15	6.82	9.22	11.14	10.18
T ₇	75% RDF + 1.0 t/ha VC + 0.5 t/ha PM	7.28	7.99	7.63	9.51	11.01	10.26
T ₈	75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)	9.36	10.28	9.82	12.79	15.31	14.05
T ₉	75% RDF + 1.0 t/ha PM + Azotobacter (4 kg/ha)	8.47	9.19	8.83	11.60	14.37	12.98
T ₁₀	75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)	9.25	9.96	9.61	12.43	14.61	13.52
T ₁₁	50% RDF + 12.0 t/ha FYM	7.59	8.71	8.15	10.08	11.55	10.82
T ₁₂	50% RDF + 2.0 t/ha PM	7.59	8.48	8.04	10.30	12.15	11.22
T ₁₃	50% RDF + 4.0 t/ha VC	7.52	8.67	8.10	10.72	12.35	11.54
T ₁₄	50% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)	8.45	9.46	8.96	11.60	14.11	12.85
T ₁₅	50% RDF + 2.0 t/ha PM + Azotobacter (4 kg/ha)	8.51	9.14	8.82	10.57	12.87	11.72
T ₁₆	50% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)	8.55	9.79	9.17	11.41	13.57	12.49
F' Test	S	S	S	S	S	S	
CD _{0.05}	0.36	0.75	0.31	0.59	0.37	0.60	
SE. m ($\pm$)	0.12	0.24	0.10	0.19	0.12	0.20	
CV. (%)	2.67	2.14	1.27	3.26	1.73	1.80	

Table 4 Effect of integrated nutrient management on neck thickness of Onion.

Neck thickness (cm)							
		60 Days after transplanting			90 Days after transplanting		
Treatment Notation	Treatment Details	2021	2022	Pooled Mean	2021	2022	Pooled Mean
T ₁	Control	1.10	1.43	1.26	1.09	1.79	1.44
T ₂	100% RDF [NPK- 120:60:60 kg/ha]	1.21	1.54	1.37	1.36	2.07	1.72
T ₃	75% RDF + 6.0 t/ha FYM	1.34	1.67	1.50	1.43	2.13	1.78
T ₄	75% RDF + 1.0 t/ha PM	1.28	1.61	1.44	1.39	2.09	1.74
T ₅	75% RDF + 2.0 t/ha VC	1.32	1.64	1.48	1.45	2.15	1.80
T ₆	75% RDF + 3.0 t/ha FYM + 0.5 t/ha PM	1.70	2.03	1.86	1.73	2.44	2.09
T ₇	75% RDF + 1.0 t/ha VC + 0.5 t/ha PM	1.31	1.64	1.47	1.57	2.28	1.92
T ₈	75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)	2.32	2.65	2.48	2.75	3.45	3.10
T ₉	75% RDF + 1.0 t/ha PM + Azotobacter (4 kg/ha)	1.96	2.28	2.12	2.45	3.16	2.80
T ₁₀	75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)	2.24	2.57	2.41	2.58	3.28	2.93
T ₁₁	50% RDF + 12.0 t/ha FYM	1.69	2.02	1.85	2.19	2.90	2.54
T ₁₂	50% RDF + 2.0 t/ha PM	1.60	1.93	1.76	1.90	2.60	2.25
T ₁₃	50% RDF + 4.0 t/ha VC	1.67	2.00	1.84	1.91	2.61	2.26
T ₁₄	50% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)	1.90	2.23	2.07	2.32	3.03	2.67
T ₁₅	50% RDF + 2.0 t/ha PM + Azotobacter (4 kg/ha)	1.79	2.12	1.96	2.17	2.88	2.52
T ₁₆	50% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)	1.85	2.18	2.02	2.34	3.05	2.69
F' Test	S	S	S	S	S	S	
CD _{0.05}	3.33	3.48	0.33	0.40	0.65	0.20	
SE. m ($\pm$)	1.07	1.12	0.11	0.13	0.21	0.07	
CV. (%)	2.42	2.66	2.69	6.68	4.32	2.82	

Table 5 Effect of integrated nutrient management on days taken to maturity of Onion.

Days taken to maturity [DAT*]				
Treatment Notation	Treatment Details	2021	2022	Pooled Mean
T ₁	Control	110.77	115.92	113.34
T ₂	100% RDF [NPK- 120:60:60 kg/ha]	106.41	113.09	109.75
T ₃	75% RDF + 6.0 t/ha FYM	105.01	111.51	108.26
T ₄	75% RDF + 1.0 t/ha PM	102.22	108.60	105.41
T ₅	75% RDF + 2.0 t/ha VC	106.36	106.75	106.55
T ₆	75% RDF + 3.0 t/ha FYM + 0.5 t/ha PM	105.94	105.57	105.76
T ₇	75% RDF + 1.0 t/ha VC + 0.5 t/ha PM	104.33	104.09	104.21
T ₈	75% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)	84.79	86.90	85.85
T ₉	75% RDF + 1.0 t/ha PM + Azotobacter (4 kg/ha)	89.19	91.37	90.28
T ₁₀	75% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)	86.96	90.18	88.57
T ₁₁	50% RDF + 12.0 t/ha FYM	94.86	99.64	97.25
T ₁₂	50% RDF + 2.0 t/ha PM	96.54	99.39	97.97
T ₁₃	50% RDF + 4.0 t/ha VC	99.88	103.85	101.86
T ₁₄	50% RDF + 6.0 t/ha FYM + Azotobacter (4 kg/ha)	92.72	97.69	95.20
T ₁₅	50% RDF + 2.0 t/ha PM + Azotobacter (4 kg/ha)	95.45	96.90	96.18
T ₁₆	50% RDF + 2.0 t/ha VC + Azotobacter (4 kg/ha)	91.28	94.93	93.10
F' Test	S	S	S	
CD _{0.05}	3.15	2.99	3.71	
SE. m (±)	1.01	0.96	1.23	
CV. (%)	1.78	1.64	1.28	

REFERENCE

1. **Anonymous (2020).** Block, E. Garlic and Other Alliums: The Lore and the Science. Royal Society of Chemistry. (2010). ISBN 978-0-85404-190-9.
2. **Afify, A.H., Hauka, F.I.A., & El-Sawah, A.M. (2018).** Plant Growth-Promoting Rhizobacteria Enhance Onion (*Allium cepa* L.) Productivity and Minimize Requisite Chemical Fertilization. *Environment and Biodiversity Soil Security*. **2**: 119-129.
3. **Cumo, C. E. (2015).** Onion. In: Foods that Changed History: How Foods Shaped Civilization from the Ancient World to the Present. ABC-CLIO LLC (*American Bibliographic Center, CLIO Press*). pp. 248–50.
4. **Dhakad, R. K., Chudasama, V. R., Verma, J., Jalpa, G., & Dhaked, M. K. (2019).** Effect of INM in Onion (*Allium cepa* L.) with Respect to Growth and Yield under North Gujarat Condition. *International Journal of Current Microbiology and Applied Sciences*. **8**(4), 1618-1622.
5. **Firbasa, P., & Amon, T. (2014).** Chromosome damage studies in the onion plant *Allium cepa* L. *Caryologia: International Journal of Cytology, Cytosystematics and Cytogenetics*. **67**(1): 25–35.
6. **Fisher, R.A. and Yates, F. (1967).** "The Design of Experiments: Statistical Principles for Practical Applications." New York: Hafner Publishing Company.
7. **Fullagar, R., Judith, F., Tim, D. and Carol, L. (2006).** Early and mid-Holocene tool use and processing of taro (*Colocasia esculenta*), yam (*Dioscorea sp.*) and other plants at Kuk Swamp in the highlands of Papua New Guinea. *Journal of Archaeological Sciences*. **33**:595-614.
8. **Gebremichael, Y., Woldetsadik, K., Chavhan, A. and Gedamu, F. (2017).** Effect of integrated nutrient management on growth and bulb yield of onion under irrigation at Selekleka. *International Journal of Life Sciences*. **5**(2):151-160.
9. **Keatinge, J., Yang, R. and Hughes, J. (2011).** The importance of vegetables in ensuring both food and nutritional security in attainment of the millennium development goals. *Food Security*. **3**(4):491-501.
10. **McNeal, Dale W. Jr.; Jacobsen, T. D. (2002).** "*Allium cepa*". In Flora of North America Editorial Committee (ed.). Flora of North America North of Mexico (FNA). Vol. 26. *New York and Oxford: Oxford University Press* – via eFloras.org, Missouri Botanical Garden, St. Louis, MO & Harvard University Herbaria, Cambridge, MA.

11. Nirala, K., Punetha, S., Pant, S. C., & Upadhaya, S. (2019). Effect of Various Organic Manures with Biofertilizers on Growth, Yield and Economics of Onion (*Allium cepa* L.). *International Journal of Current Microbiology and Applied Sciences*. 8(1), 3092-3099.
12. Priyanshu, Pal, S. L., Ravi, Shoraj Singh, & Kumar, V. (2020). Effect of organic manure and inorganic fertilizer on growth yield and yield attributes in onion (*Allium cepa* L.) under Dhampur (Bijnor) condition. *International Journal of Chemical Studies*. 8(6), 635-637.
13. Prusty, M., Mishra, N., Kar, D.S., & Pal, S. (2019). Effect of integrated nutrient management on growth and yield of onion (*Allium cepa* L.) cv. Bhima Super. *International Journal of Agriculture Sciences*. 11(4), 7910-7912.
14. Sharangi, A. B. and Datta, S. (2005). Medicinal properties of spices. *Indian Journal of Areca nut, Spices and Medicinal Plants*. 7: 42-49.
15. Singh, M.K., Singh, D.K., Singh, R.K., & Mishra, S.K. (2021). Integrated effect of biofertilizers and inorganic fertilizers on growth, yield and quality of onion (*Allium cepa* L.). *The Pharma Innovation Journal*. 10(2), 104-107.
16. Singh, G., Kumar, R., Singh, S. and Thakur, K. S. (2019). Effect of integrated nutrient management on some growth characteristics of onion (*Allium cepa* L.). *Journal of Pharmacognosy and Phytochemistry*. 553-556.
17. Singh, V.V., Mauriya, S.K., Pal, S., Ram, R.B., & Yadav, S.P. (2020). Effect of Bio-fertilizers on Growth, Yield and Quality Traits of Onion (*Allium cepa* L.). *International Research Journal of Pure & Applied Chemistry*. 21(10), 18-22.
18. Singh, V. (2022). Impact of integrated nutrient management on soil fertility and yield of onion (*Allium cepa*) on an alluvial soil. *Annals of Plant and Soil Research*. 24(2), 337-341.
19. Singh, R., Singh, N., & Singh, B. K. (2023). Response of Organic Manures with Macro and Micronutrients on Growth and Yield of Onion cv. N-53. *Journal of AgriSearch*. 9(1), 50-53.
20. Singh, S., Singh, P.K., Dixit, P.S., Singh, R.B., Pyare, R., Bhayankar, c., & Ranjan, A.R. (2023). Integrated Effect of Inorganic Fertilizers and Biofertilizers on Growth and Yield of Onion (*Allium cepa* L.). *International Journal of Environment and Climate Change*. 13(10), 1234-1238.
21. Walkley, A., & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science*, 37(1), 29-38.
22. Yogita, & Ram, R.B. (2012). Effect of chemical and bio-fertilizers on quality of onion. *HortFlora Research Spectrum*. 1(4), 367-370.



INTEGRATED IMPACT OF INORGANIC AND BIO-FERTILIZERS ON GROWTH AND YIELD ATTRIBUTES OF BROAD BEAN (*VICIA FEBA* L.) CV. PUSA UDIT

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ABSTRACT

The present investigation was conducted during the winter season of 2021-22 at the Horticulture Research Farm, Department of Horticulture, Janta Vedic College, Baraut, Baghpat (U.P.), India. The study aimed to evaluate the combined effects of inorganic and bio-fertilizers on the growth and yield of broad beans. The experiment was laid out in a Randomized Block Design (RBD) with seven treatments: T₀ (control), T₁ (100% NPK), T₂ (75% NPK + *Rhizobium*), T₃ (75% NPK + VAM), T₄ (75% NPK + *Azospirillum*), T₅ (75% NPK + *Rhizobium* + VAM) and T₆ (75% NPK + *Azospirillum* + VAM), with three replications. The results showed that the integrated application of *Rhizobium* and VAM with reduced NPK (T₅) significantly enhanced various growth parameters, including the highest seed germination (97.97%), plant height (88.25 cm), leaf length (6.12 cm), leaf width (3.15 cm) and the number of branches per plant (8.06). Additionally, T₅ treatment also led to earlier flowering (45.56 days after sowing) and superior yield attributes, such as the maximum number of pods per plant (49.61), pod weight (4.07 g), number of seeds per pod (4.40), pod length (5.20 cm), seed index (140.75 g) and pod yield (304.13 q/ha). The study concludes that the application of 75% NPK in combination with *Rhizobium* and VAM is highly effective in improving both the growth and yield of broad beans under Delhi NCR conditions.

Keywords:

INTRODUCTION

Broad bean (*Vicia faba* L.), commonly known as fava bean, is an important leguminous crop widely cultivated for its nutritious seeds and as a valuable source of plant protein (5). It plays a crucial role in sustainable agriculture due to its ability to fix atmospheric nitrogen, thus improving soil fertility and reducing the need for chemical fertilizers (10). However, to achieve optimal growth and yield, the crop still requires an

adequate supply of essential nutrients, which are often supplemented through the application of inorganic fertilizers (8). Inorganic fertilizers, particularly those containing nitrogen (N), phosphorus (P), and potassium (K), have been traditionally used to enhance crop productivity. While effective, the excessive and continuous use of these fertilizers can lead to soil degradation, nutrient imbalances and environmental pollution (9). In response to these challenges,

the integration of bio-fertilizers, which are natural and eco-friendly alternatives, has gained attention as a sustainable approach to improving crop yield while maintaining soil health. Bio-fertilizers, including *Rhizobium*, *Vesicular Arbuscular Mycorrhiza* (VAM) and *Azospirillum*, are known for their ability to enhance nutrient availability, stimulate plant growth, and improve soil structure (1).

Rhizobium, a nitrogen-fixing bacterium, forms symbiotic associations with leguminous crops, aiding in atmospheric nitrogen fixation. VAM, a type of mycorrhizal fungi, enhances phosphorus absorption and mobilization in plants (3). *Azospirillum*, another beneficial bacterium, promotes root growth and overall plant vigor. The integration of bio-fertilizers with inorganic fertilizers has the potential to maximize the efficiency of nutrient use, reduce dependency on chemical inputs and promote sustainable agricultural practices. This approach not only enhances crop productivity but also contributes to the conservation of natural resources and environmental protection. The primary objective of this study was to evaluate the effectiveness of combining reduced levels of NPK with bio-fertilizers, specifically *Rhizobium*, VAM and *Azospirillum*, in enhancing the growth and yield attributes of broad beans cv. Pusa Udit under Delhi NCR conditions.

MATERIALS AND METHODS

The present investigation was carried out during the *Rabi* season of 2021-22 at the Horticulture Research Block, Janta Vedic College, Baraut, Baghpat, Uttar Pradesh (29.1058°N, 77.2661°E). The study aimed to evaluate the effectiveness of combining reduced levels of NPK with bio-fertilizers, specifically *Rhizobium*, VAM and *Azospirillum*, in enhancing the growth and yield attributes of broad beans cv. Pusa Udit under Delhi NCR conditions. Broad bean cultivar Pusa Udit was taken as test crop. The

study was laid out in a randomized block design with six treatments along with a control and three replications. The treatments included: T₀ (control), T₁ (100% RDF), T₂ (75% RDF + *Rhizobium*), T₃ (75% RDF + VAM), T₄ (75% RDF + *Azospirillum*), T₅ (75% RDF + *Rhizobium* + VAM) and T₆ (75% RDF + *Azospirillum* + VAM). Seeds were soaked for 24 hours and then exogenous application of bio-fertilizers done as per treatment details. Seeds were sown on 23rd November 2021 in raised beds, spaced 0.45m between rows and 0.15m between plants. Standard cultural practices recommended for broad bean were followed uniformly for all the experimental plots. Application of nitrogen, phosphorus and potassium were applied in the form of urea, single super phosphate and murate of potash, respectively. Growth parameters such as germination percentage, plant height, leaf dimensions and number of branches, along with yield attributes including pod length, pod weight and seed index were recorded to assess the effects of the treatments. The data were statistically analyzed using ANOVA for the Randomized Block Design, following the procedures outlined by (6).

RESULTS AND DISCUSSION

Growth attributes

The maximum seed germination (97.97%) was observed in treatment T₅ (75% NPK + *Rhizobium* + VAM), which was at par with treatment T₆ (75% NPK + *Azospirillum* + VAM) with 97.58%. The minimum germination (92.26%) was recorded in the control (T₀). Treatment T₅ also resulted in the tallest plants, with an average height of 88.25 cm, surpassing T₁ (100% NPK) with 85.05 cm, while the control (T₀) had the shortest plants (70.37 cm). In terms of leaf development, treatment T₅ led to the maximum leaf length (6.12 cm) and width (3.15 cm), followed by T₁, while T₀ had the smallest leaf dimensions (Table 1). Treatment T₅ also produced the

highest number of branches per plant (8.06) at par with treatment T₁ (7.55), whereas T₀ recorded the minimum number of branches (3.52). The observed increase in plant height, particularly in treatments involving *Rhizobium* and VAM, can be linked to the biological activity of these bio-fertilizers. *Rhizobium*, known for its ability to fix atmospheric nitrogen through root nodules, provides a steady nitrogen supply, which is crucial for promoting vegetative growth, resulting in taller plants with more numbers of branches. This is supported by the findings of (14) and (11), who reported similar enhancements in plant height and branching due to nitrogen fixation by *Rhizobium*. Additionally, the role of nitrogen in promoting plant height is well-documented. Nitrogen is essential for vegetative growth, leading to increased cell division and elongation.

Yield Attributes

Flowering was earliest in treatment T₅, with flowers appearing in 45.56 days after sowing, compared to the flowering in the control (T₀) at 58.36 days (Figure 1). Treatment T₅ also produced the maximum number of pods per plant (49.61) and the maximum weight of pods (4.07 g), which was at par with treatment T₆ (Table 2). The minimum number of pods (40.81) and minimum pod weight (2.67 g) were observed in the control i.e. untreated. This increase can be attributed to potassium's role in enhancing enzyme activity, which improves protein and carbohydrate synthesis and their transfer from source to sink (13). Additionally, nitrogen and phosphorus are crucial elements in plant nutrition that contribute to overall growth and yield. These findings align with the observations of (4), who highlighted the importance of these nutrients in optimizing plant performance.

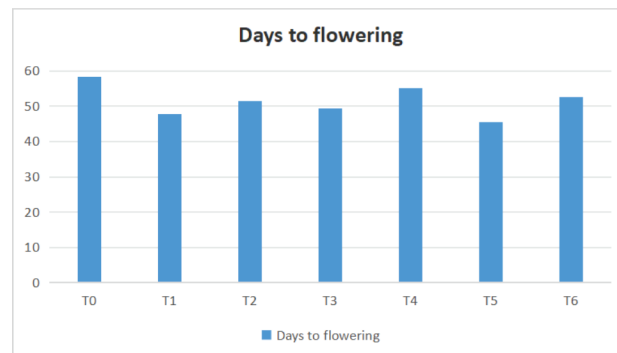


Figure 1: Integrated impact of Inorganic and Bio-fertilizers on days to of broad bean cv. Pusa Udit

Moreover, treatment T₅ yielded the highest number of seeds per pod (4.40), the longest pods (5.20 cm) and the highest seed index (140.75 g), while the control showed the lowest values across these metrics (Table 2). The most significant finding was the pod yield, where T₅ recorded 304.13 q/ha, significantly outperforming the control, which produced only 184.33 q/ha (Figure 2). This increase may be attributed to the role of bio-fertilizers in enhancing nitrogen availability and producing growth-promoting substances, which delay plant aging and extend the seed-filling period. As a result, there is an increase in seed weight. This finding is consistent with the observations of Ara et al. (2009), who noted that the application of bio-fertilizers can positively affect seed development and overall pod yield. The current results align closely with the previous findings made by (7, 12 and 2).

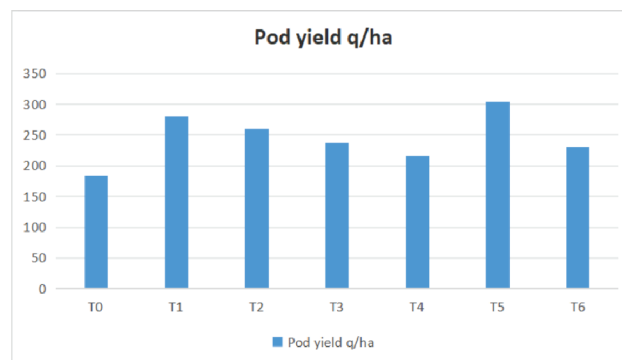


Figure 2: Integrated impact of Inorganic and Bio-fertilizers on pod yield of broad bean cv. Pusa Udit

Table 1: Integrated impact of Inorganic and Bio-fertilizers on growth attributes of broad bean cv. Pusa Udit

Treatment	Seed Germination (%)	Plant height (cm)	Leaf length (cm)	Leaf width (cm)	Number of branches /plant
Control	92.26	70.37	5.07	2.5	3.52
100% NPK	93.58	85.05	6.03	2.96	7.55
75% NPK + <i>Rhizobium</i>	95.30	82.85	5.96	2.83	7.40
75% NPK + VAM	94.81	81.12	5.85	2.75	7.06
75% NPK + <i>Azospirillum</i>	96.33	78.41	5.63	2.66	5.95
75% + <i>Rhizobium</i> + VAM	97.97	88.25	6.12	3.15	8.06
75% NPK + <i>Azospirillum</i> +VAM	97.58	79.92	5.95	2.74	6.50
C.D. (p=0.05)	0.53	0.94	0.38	0.09	0.47

Table 2: Integrated impact of Inorganic and Bio-fertilizers on yield attributes of broad bean cv. Pusa Udit

Treatment	No of pod/plant	Pod weight (gm)	No of seed /pod	Pod length (cm)	Seed index
Control	40.81	2.67	3.58	4.18	95.72
100% NPK	47.48	3.72	4.26	4.96	133.10
75% NPK + <i>Rhizobium</i>	45.68	3.67	4.12	4.84	129.79
75% NPK + VAM	44.73	3.34	3.99	4.71	126.60
75% NPK + <i>Azospirillum</i>	43.77	3.19	3.77	4.55	121.81
75% + <i>Rhizobium</i> + VAM	49.61	4.07	4.40	5.20	140.75
75% NPK + <i>Azospirillum</i> +VAM	44.42	4.05	3.91	4.65	125.18
C.D. (p=0.05)	0.53	0.48	0.12	0.23	0.76

CONCLUSION

On the basis of above findings it may be concluded that application of 75% NPK along with *Rhizobium* and VAM was found beneficial to enhance the growth and yield of broad bean under Delhi NCR conditions.

REFERENCES

1. Abd-Alla, M.H., El-Enany, A.W.E., Nafady, N.A., Khalaf, D.M. and Morsy, F.M., 2014. Synergistic interaction of *Rhizobium leguminosarum* bv. *viciae* and *arbuscular mycorrhizal* fungi as a plant growth promoting biofertilizers for faba bean (*Vicia faba* L.) in alkaline soil. *Microbiol Res*, 169: 49–58.
2. Badr, E.A., Amany, A., Bahr, G.A.A. and Asal, M.W. (2014). Response of Sweet Lupin (*Lupinus albus* L.) to Spraying with Molybdenum, Bio and Nitrogen fertilizer on Seed yield and quality. *Middle East Journal of Agriculture Research*, 3(2): 363-367.
3. Chakrabarti, J., Chatterjee, S., Ghosh, S., Chatterjee, N. C., and Dutta, S. (2010). Synergism of VAM and *Rhizobium* on production and metabolism of IAA in roots and root nodules of *Vigna mungo*. *Current Microbiology*, 61(3), 203-209. <https://doi.org/10.1007/s00284-010-9597-2>
4. El-Shouny, K.A., Abdel-Gawad, A.A., El-Gind, A.M. and Sorour, H.A. (2001). Studies on phosphatic fertilization and irrigation of mung bean. Individual effect of phosphatic fertilization, water regime and irrigation system on yield and quality. *Arab Univ. J. Agri. Sci.*, 9(1): 213-223.
5. Fageria, M.S., Dhaka, R.S. and Choudhary, B.S., 2022. Beans. In book *Vegetable Crops Production Technology* (Vol.-2). Kalyani Publisher.
6. Gomez, K. A. and Gomez, A. A. (1984). *Statistical procedures for Agricultural Research*, John Wiley and Sons, New York.
7. Khudair, D. S. and Jasim, A. H. (2019). Response of some broad bean (*Vicia faba* L.) varieties to bio and chemical fertilization on seed yield. *Plant Archives*, 19(Supplement 1), 246-251.

8. Lodhi, P., Singh, D., and Tiwari, A. (2017). Effect of inorganic and organic fertilizers on yield and economics of broccoli (*Brassica oleracea* var. *italica*). *International Journal of Current Microbiology and Applied Sciences*, 6(8), 562-566. <https://doi.org/10.20546/ijcmas.2017.608.073>
9. Meena, V. K., Dubey, A. K., Jain, V. K., Tiwari, A., and Negi, P. (2017). Effect of plant growth promoters on flowering and fruiting attributes of okra (*Abelmoschus esculentus* (L.) Moench). *Crop Research*, 52(1, 2 & 3), 37-40.
10. Rana, M.K. and Vilas, C.A. 2017. Broad Bean. In book: Vegetable Crop Science edited by Rana, M.K., CRC Press. Tylor and Francis Group. DOI: 10.1201/9781315116204-75
11. Rudresh, D., Shivaprakash, M. and Prasad, R. (2005). Effect of Combined Application of Rhizobium, Phosphate Solubilizing Bacterium and *Trichoderma* spp. on Growth, Nutrient Uptake and Yield of Chickpea (*Cicer aritenium* L.). *Applied Soil Ecology*, 28, 139-146. <http://dx.doi.org/10.1016/j.apsoil.2004.07.005>.
12. Shafeek, M.R.; Faten S.A. and Aisha, H.A. (2004). The productivity of broad bean plant as affected by chemical and/or natural phosphorus with different bio-fertilizer. *Journal of Agricultural Sciences*, 29 (5): 2727-2740.
13. Taiz, L. and Zeiger, E. (2006). Plant Physiology, fourth ed., Sinauer Associates, Sunderland, 2006.
14. Zahran, H.H. (1999). Rhizobium-Legume Symbiosis and Nitrogen Fixation under Severe Conditions and in an Arid Climate. *Microbiology and Molecular Biology Reviews*, 63, 968-989.



IMPACT OF FOLIAR APPLICATION OF PLANT BIO-REGULATOR AND MICRO-NUTRIENTS ON FRUIT RETENTION, YIELD AND QUALITY ATTRIBUTES OF AONLA

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ABSTRACT

An experiment was carried out in the Garden, Department of Fruit Science, C. S. Azad University of Agriculture and Technology, Kanpur (UP) in 2023 to investigate the impact of foliar application of plant bio-regulator and micronutrients on fruit drop, retention, yield, and quality attributes of Aonla, using nine treatments *viz.*, NAA at 20 and 40 ppm; Borax at 0.2% and 0.4% and Zinc sulphate 0.3% and 0.6%, NAA @ 20 ppm + Borax @ 0.2% + ZnSO₄ @ 0.3%, NAA @ 40 ppm + Borax @ 0.4% + ZnSO₄ @ 0.6% including a control treatment (water spray) on twenty-three old trees of aonla cv. NA-7 replicated thrice in Randomized Block Design. From the experiment, it is recorded that the higher concentration of NAA @ 40ppm + Borax 0.4% + zinc sulphate 0.6% significantly reduces fruit drop (23.80%) with maximum fruit retention (76.20%), fruit yield (89.88kg/plant), fruit length (4.66cm), fruit breadth (5.04cm), fruit volume (27.56cc), fruit weight (29.95g), specific gravity (1.08g/cc), pulp weight (43.92g), pulp: stone ratio (42.84), TSS (13.12°Brix), ascorbic acid (627.24mg/100g pulp), TSS: acid ratio (9.86), total sugars (11.19%) and with minimum stone weight (1.08g) and titratable acidity (1.33%) followed by NAA 20 ppm + Borax 0.2% + zinc sulphate 0.3% (T₇) as compared to control (T₀) treatments.

Keywords: Aonla, NAA, Micronutrients, Fruit retention, Yield and Quality attributes.

INTRODUCTION

Aonla (*Emblica officinalis* Gaertn.) belongs to the family Euphorbiaceae and is said to be indigenous to tropical Southeast Asia, especially in the Central and Southern parts of India (Morton, 1960). The Indian gooseberry fruit pulp is a key component of the powdered triphala and chyawanprash, which treat various disorders. The fruit is often used to make canned food (murabba), pickles, candies, jams, sauces, dried chips, and other products. Fruits contain water (81.2%), protein (0.5%),

fat (0.1%), carbohydrates (14.1%), calcium (0.05%), phosphorus (0.02%), and iron (1.2%). It contains phenols, polyphenols, tannins, and alkaloids and is a powerful source of vitamin C (600 mg/100 g pulp), more than guava and citrus fruits.

Aonla is hardy and drought-resistant, with a deep root system and a deciduous appearance since it sheds its determinate shoots in February and March. It is successfully cultivated in a wide range of soil (Sodic and saline soil), but well-drained, fertile loamy soil is the best for cultivation. It can also

do well even in the moderately alkaline soil. Climatic conditions of arid and semi-arid to dry hot and cold arid regions, rain-fed to rainfall area suitable for aonla cultivation. The effective management of accessible natural resources is crucial to the success of organic agriculture in dry environments (Shukla *et al.* 2004).

The foliar application of plant growth regulators and micronutrients is vital in improving fruit set, productivity and quality. It also has a beneficial role in recovering nutritional and physiological disorders in fruit trees. Plant growth regulators play a significant role in manipulating many physiological phenomena. There has been widespread application of plant growth regulators in service of the fruit industry. Naphthalene acetic acid (Auxin) increased fruit set, decreased fruit drop and brought a beneficial change in the quality of many fruits. NAA also inhibits fruit drop by strengthening the pedicle. In this concept, many scientists have done various work on different fruit crops, including aonla, to observe the distinct emphasis on enhancement in growth, flowering, fruiting and quality yield attributes.

In India, widespread deficiency of micronutrients, especially zinc and boron, in horticultural crops has been reported. The problem of reduced yield and sometimes reduced quality due to necrosis and fruit drop is associated with a deficiency of boron and other micronutrients. Indian gooseberry is a minor fruit crop, and no systematic research work has been carried out to improve the fruit set, yield, and quality of aonla fruit by boron (Singh *et al.*, 1989). Boron also plays a vital role in ovule development, pollen tube growth, and fruit set. The intensity of damage caused by fruit dropping can also be minimized by the foliar application of PBRs and nutrients, which also helps improve the yield and fruit quality of aonla.

Similarly, zinc also plays an important role in the growth and development of fruits. It is one of the essential elements for forming chlorophyll and, hence, is helpful for photosynthetic activity. Zinc is a constituent of some enzymes, indole acetic acid in plants and is necessary for CO₂ evolution, utilization of carbohydrates, and phosphorus metabolism and effective in retaining the maximum fruit percentage per panicle with the increase in fruit size and fruit weight in many fruits (Tripathi and Viveka Nand, 2022). Keeping these in view, the present investigation was carried out to study the influence of NAA, boron and Zinc sulphate on aonla fruits.

MATERIALS AND METHODS

The study was conducted with 23-year-old aonla trees planted in the Garden, Department of Fruit Science, C.S. Azad University of Agriculture and Technology, Kanpur (U.P.). Twenty-seven well-established healthy and uniform trees of aonla cv. NA-7 were selected for the experimental purpose. The trees were maintained under uniform cultural operations throughout the experiment. The 27 trees having uniform growth were selected randomly for foliar application of micro-nutrients and bio-regulators. The experiment was laid out in a randomized block design with nine treatments viz., T₀-Control (Water spray), T₁-NAA 20 ppm, T₂-NAA 40 ppm, T₃-Borax 0.2%, T₄-Borax 0.4%, T₅-ZnSO₄ 0.3%, T₆-ZnSO₄ 0.6%, T₇- NAA @ 20 ppm + Borax @ 0.2% + ZnSO₄ @ 0.3%, T₈- NAA @ 40 ppm + Borax @ 0.4% + ZnSO₄ @ 0.6% with three replications.

The foliar application of NAA and micronutrients was done at the fruit setting on August 8, 2023 and fruit developmental stage on September 14, 2023, respectively. The standard cultural operations, plant protection measures, and basal application of manures and fertilizers were made as per the

recommended schedule for aonla plantation in all treatments. The observations were recorded on fruit drop, fruit retention and yield with various other physico-chemical parameters of fruits and obtained data were analyzed statistically. Hand refractometer was used for the determination of TSS, which is represented in °Brix. Other chemical parameters, *viz.* total sugars, ascorbic acid and titratable acidity were determined by the standard method as described in AOAC (1980).

RESULTS AND DISCUSSION

Fruit drop and retention per cent:

The present study observed that significantly reduced fruit drop and higher fruit retention percentage were observed in the plants treated with plant bio-regulators and micronutrients (Table 1). Reduced amount of fruit drop (23.80%) and higher fruit retention (76.20%) were recorded with the application of NAA @ 40 ppm + Borax @ 0.4% + ZnSO₄ @ 0.6%. In contrast, the maximum fruit drop (76.85%) with minimum fruit retention (23.15%) percentage were recorded under control. The reduction in fruit drop and increase in fruit retention percentage by the borax spray may be due to the indirect action of boron in auxin synthesis that delayed the formation of the abscission layer during the early stage of fruit development (3). Various workers such as (6) in ber cv. Gola, (21) litchi cv. Purvi and Tiwari *et al.* (2017) in aonla have also reported reduced fruit drop.

Fruit yield (kg/plant)

The foliar application of plant bio-regulators and micronutrient treatments significantly increased the fruit yield per plant as compared to the control (Fig. 1). Foliar application of NAA, Borax and ZnSO₄ by the increase in the concentration of plant bio-regulator and micronutrients, significantly improvement in the yield take

place and yield of 89.88kg/plant was recorded under higher concentration of NAA @ 40 ppm + Borax @ 0.4% + ZnSO₄ @ 0.6%. In contrast, the lowest fruit yield of 33.87kg/plant was recorded under Control (T₀). This significant increase in fruit yield when the combined application of NAA, Borax and ZnSO₄ treated plants might be due to their direct role in the synthesis of photosynthates in the plants, which increase fruit size, weight and volume, which ultimately increases the yield of fruits. Results regarding fruit yield are in agreement with that of (14) in guava, (20) in strawberry cv. Chandler and Tripathi *et al.* (2018) in aonla cv. NA-7.

Fruit size (length and width) (cm)

In the present investigation, fruit size (length and width) was significantly increased with the foliar application of plant bio-regulator and micronutrients (Table 1). Plants treated with NAA @ 40 ppm + Borax @ 0.4% + ZnSO₄ @ 0.6% produced significantly higher fruit length (4.66 cm) and breadth (5.04 cm). Meanwhile, the plants kept under control produced fruits with shorter lengths (3.31 cm) and breadths (4.08 cm) of fruits. This improvement in fruit size might be due to the greater mobilization of food materials from their production site to the storage organs under the influence of applied plant bio-regulator and micro-nutrients. Since boron plays an important role in nitrogen metabolism and other changes in fruits, thus it might have increased the fruit size. Thus, increases in the size of fruits with the application of NAA, Borax, and ZnSO₄ might be due to the significant increase in cell division and cell enlargement by NAA treatment. The obtained results are in agreement with the findings of Tripathi *et al.* (2018) in aonla cv. NA-7, (7) in Kinnow mandarin and (16) in aonla cv Banarasi.

Fruit weight and volume

The weight and volume of fruits were

significantly influenced by the foliar application of NAA, Borax and ZnSO_4 (Table 1). Significantly higher weight (29.95 g) and volume (27.56 cc) were recorded in fruits treated with NAA @ 40 ppm + Borax @ 0.4% + ZnSO_4 @ 0.6%. It is also observed that with the reduction in dose of plant bio-regulator and micronutrients, the fruit weight and volume also get reduced but remain significantly higher as compared to control, which produced minimum fruit weight (25.32 g) and volume (24.88 cc). This increase in weight and volume of fruits might be due to a better supply of nutrients and photosynthates in plants treated with foliar application of NAA, Borax and ZnSO_4 , which might have made a rapid synthesis of metabolites mainly carbohydrate and their translocation to the fruits, causing relatively greater pulp content. Boron is an essential nutrient that is involved in several physiological processes in fruit, involving in the maintenance of cell wall integrity and upto some extent found inhibiting the senescence of litchi fruits. These results per the findings of (16) in aonla cv. Banarasi, Saraswat *et al.* (2006) and Ruby and Brahmachry (2001) in litchi.

Fruit specific gravity

All the treatments of plant bio-regulator and micronutrients applied showed significant effects on the specific gravity of fruit (Table 1). It is observed that fruits with higher specific gravity (1.08 g/cc) were produced from the plants treated with NAA @ 40 ppm + Borax @ 0.4% + ZnSO_4 @ 0.6%, while fruits with minimum specific gravity (1.01g/cc) were produced from untreated control plants, kept without any treatment. This increase in specific gravity with higher concentration of NAA and micronutrients (Borax and ZnSO_4) might be due to an increased fruit pulp and decreased stone weight. These findings are in accordance with the results of Shukla *et al.* (2011), Singh and Singh (2015), Singh *et al.* (2016) in aonla.

Fruit pulp weight

Fruit pulp weight was significantly increased by the foliar application of plant bio-regulator and micronutrients (Table 1). Significantly more weight of pulp (43.92 g) was recorded in fruits, which were harvested from the plants treated with the NAA @ 40 ppm + Borax @ 0.4% + ZnSO_4 @ 0.6% closely followed by (41.15 g) was produced from T₇ (NAA 20 ppm + Borax 0.2 % + ZnSO_4 0.3%) treatment, whereas fruits with minimum pulp weight (31.53 g) were recorded from untreated (control) plants. This increase in fruit pulp weight with the application of zinc is due to the direct involvement of zinc in the acceleration of biochemical activity in plant parts and the translocation of mineral nutrients during the fruit development process. These findings conform with the findings of Chaturvedi *et al.* (2005) in strawberry, Verma *et al.* (2016) in aonla and Meena *et al.* (2008) in ber.

Fruit stone weight and pulp: stone ratio

Reduction in stone weight with increased pulp: stone ratio was recorded using plant bio-regulator and micronutrients as compared to control (Table 2). The minimum weight of stone (1.08 g) and higher pulp: stone ratio (42.84) was recorded in the fruits produced from the plants treated with NAA @ 40 ppm + Borax @ 0.4% + ZnSO_4 @ 0.6%, whereas the maximum weight of stone (1.45 g) was recorded under control (untreated) plants and minimum pulp: stone ratio (23.58) was produced from the foliar application of NAA 20 ppm (T₁). This improvement in pulp: stone ratio might be due to more accumulation of food substances in elongated cells and intercellular space of the mesocarp. These results have been supported by the findings of Verma *et al.* (2016), Tiwari *et al.* (2017), Kumar *et al.* (2017) and Singh *et al.* (2016) in aonla.

TSS and total sugars

The maximum TSS and total sugars content (13.12°Brix and 11.19%, respectively) were recorded in the fruits produced from the plants treated with the foliar application of NAA @ 40 ppm + Borax @ 0.4% + ZnSO₄ @ 0.6%, followed by 11.65°Brix of TSS and 9.68% of total sugars, respectively were recorded from the plants treated with the application of NAA @ 20 ppm + Borax @ 0.2% + ZnSO₄ @ 0.3%. In contrast, the minimum TSS (9.73°Brix) and total sugars (7.27 %) were recorded under (control) untreated plants (Table 2). This increase in TSS and total sugars with NAA, boron and zinc sulphate application might be because these plant bio-regulator and micronutrients are helpful in the process of photosynthesis, which leads to the accumulation of oligosaccharides and polysaccharides in higher amounts besides this they also regulate the enzymatic activity and metabolize the carbohydrates into simple sugars. Tiwari *et al.* (2017) in aonla and Gupta *et al.* (2022) in litchi also recorded an increase in total sugar and TSS content with higher concentrations of boric acid treatments. These results conform with the findings of Shukla *et al.* (2011), Verma *et al.* (2016), Singh and Singh (2015), Singh *et al.* (2016) in aonla, Gand Rajak *et al.* (2010) in mango cv. Amrapali.

Titrateable acidity

Titrateable acidity content in fresh fruits was decreased by the significant effect of the application of plant bio-regulator and micronutrients (Table 2). The minimum titrateable acidity (1.33%) was found in the fruits produced from the plants treated with NAA @ 40 ppm + Borax @ 0.4% + ZnSO₄ @ 0.6%, closely followed by titrateable acidity (1.37%) from NAA (20 ppm) + Borax (0.2 %) + ZnSO₄ (0.3%) application. In contrast, the maximum content (1.86 %) was recorded in fruits produced from untreated control plants (Table 2). This decrease in the titrateable acidity content of fruits might be due to

increased TSS and total sugars. The acids under the influence of chemicals might have either been converted into sugars and their derivatives by the reactions involving reversal of glycolytic pathway or may be used as a substratum in the respiration or both. The results support the findings of Shukla *et al.* (2011) in aonla cv. Banarasi, Singh and Singh (2015), Verma *et al.* (2016), Tripathi and Shukla (2011) and Singh *et al.* (2016) in aonla.

Ascorbic acid

The maximum ascorbic acid content (626.94 mg/100g pulp) was recorded in the fruits produced from the plants treated with NAA @ 40 ppm + Borax @ 0.4% + ZnSO₄ @ 0.6% closely followed by (623.91 mg/100g pulp) and (620.56 mg/100g pulp) with NAA @ 20 ppm + Borax @ 0.2% + ZnSO₄ @ 0.3%, respectively, which remained higher than rest of the treatments. In contrast, the minimum ascorbic acid (610.43 mg/100g pulp) was obtained from the control treatment. This increase in ascorbic acid content with NAA, Borax, and Zinc application is due to uninterrupted synthesis of its precursor like glucose-6-phosphate during the conversion of starch into various sugars and a low oxidation rate. The finding is in accordance with the results of Shukla *et al.* (2011), Tripathi and Shukla (2011), Singh and Singh (2015), Verma *et al.* (2016) and Singh *et al.* (2016) Kumar *et al.* (2017), Tiwari *et al.* (2017) in aonla and Raghava and Tiwari (1998) in guava.

TSS: Acid ratio

TSS: acid ratio showed a significant effect when applying plant bio-regulator and micronutrients (Table 2). The higher TSS: acid ratio (9.86) was recorded with the application of NAA @ 40 ppm + Borax @ 0.2% + ZnSO₄ @ 0.6%. Meanwhile, the minimum TSS: acid ratio (5.23) was recorded under control (untreated) plants. This might be because of an increase in the TSS and decreases in the titrateable acidity of fruits. These findings are the results of Tripathi and Shukla (2011).

Table 1. Effect of foliar application of NAA, Boron and Zinc sulphate on physical attributes of aonla.

Treatments	Fruit drop (%)	Fruit retention (%)	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Fruit volume (cc)	Specific gravity (g/cc)	Pulp weight (g)
T ₀ -Control	76.85	23.15	3.31	4.08	25.32	24.88	1.01	31.53
T ₁ -NAA (20 ppm)	54.78	45.22	3.52	4.47	28.56	27.26	1.04	32.79
T ₂ -NAA (40 ppm)	46.26	53.74	3.81	4.55	26.06	25.21	1.03	33.37
T ₃ -Borax (0.2%)	43.3	56.70	3.83	4.61	26.06	25.21	1.03	34.67
T ₄ -Borax (0.4 %)	40.91	59.09	3.94	4.67	27.72	25.76	1.07	34.51
T ₅ -ZnSO ₄ (0.3%)	39.17	60.83	4.01	4.75	26.65	25.08	1.06	35.55
T ₆ -ZnSO ₄ (0.6%)	35.02	64.98	4.10	4.88	26.15	24.68	1.05	38.20
T ₇ - NAA @ 20 ppm + Borax @ 0.2% + ZnSO ₄ @ 0.3%	28.06	71.94	4.23	4.95	28.28	26.36	1.07	41.15
T ₈ - NAA @ 40 ppm + Borax @ 0.4% + ZnSO ₄ @ 0.6%	23.80	76.20	4.66	5.04	29.95	27.56	1.08	43.92
S.E. (m)±	0.83	1.65	0.10	0.02	1.04	0.51	0.01	1.96
CD at 5%	2.51	4.99	0.32	0.08	2.18	1.08	0.04	5.94

Table 2. Effect of foliar application of NAA, Boron and Zinc sulphate on physico-chemical attributes of aonla cv. NA-7.

Treatments	Stone weight (g)	Pulp: stone ratio	TSS (°Brix)	Total sugar (%)	Titrateable acidity (%)	TSS: acid ratio	Ascorbic acid (mg/100g pulp)
T ₀ -Control	1.45	30.08	9.73	7.27	1.86	5.23	610.43
T ₁ -NAA (20 ppm)	1.39	23.58	10.06	7.88	1.58	6.36	611.48
T ₂ -NAA (40 ppm)	1.36	24.53	10.69	8.50	1.59	6.72	613.88
T ₃ -Borax (0.2 %)	1.32	33.35	10.70	8.65	1.45	7.37	613.41
T ₄ -Borax (0.4 %)	1.25	33.26	10.91	8.83	1.48	7.37	547.95
T ₅ -ZnSO ₄ (0.3%)	1.21	34.34	10.16	8.14	1.42	7.15	616.84
T ₆ -ZnSO ₄ (0.6%)	1.16	37.04	10.87	8.87	1.40	7.76	620.58
T ₇ - NAA @ 20 ppm + Borax @ 0.2% + ZnSO ₄ @ 0.3%	1.10	40.05	11.65	9.68	1.37	8.50	623.65
T ₈ - NAA @ 40 ppm + Borax @ 0.4% + ZnSO ₄ @ 0.6%	1.08	42.84	13.12	11.19	1.33	9.86	627.24
S.E. (m)±	0.005	1.27	0.24	0.26	0.02	0.24	0.26
CD at 5%	0.015	3.84	0.74	0.81	0.06	0.79	0.79

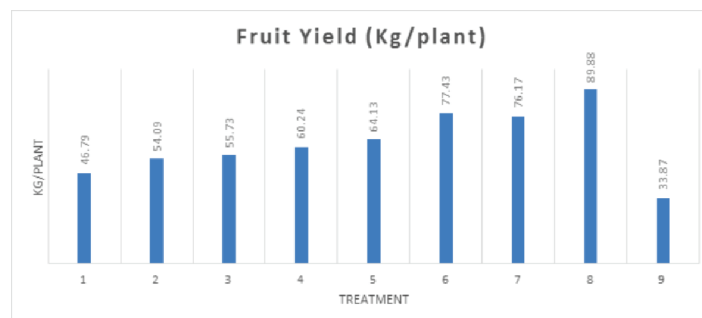


Fig. 1. Impact of foliar application of plant NAA, Boron and Zinc Sulphate on fruit yield (kg/plant) of aonla cv. NA-7.

CONCLUSION

From the results obtained during present investigation, it can safely be concluded that plants treated with NAA @ 40 ppm + Borax @ 0.4% + ZnSO₄ @ 0.6% have significantly reduced fruit drop with increased fruit retention along with physical parameters like fruit size (length and breadth), fruit weight, fruit volume, fruit specific gravity, pulp weight, fruit yield (kg/plant), as well as chemical attributes like TSS, total sugars and ascorbic acid content of fruits and reduced stone weight. To obtain a higher yield with quality fruits in aonla, plants should be sprayed with a combined application of NAA @ 40 ppm + Borax @ 0.4% + ZnSO₄ @ 0.6% under the north Indian plains of Uttar Pradesh.

REFERENCES

1. AOAC (1980). *Official Methods of Analysis*. Association of Official Analytical Chemists, Washington DC.
2. Chaturvedi, O.P., Singh, A.K., Tripathi, V.K. and Dixit, A.K. (2005). Effect of zinc and iron on growth, yield and quality of Strawberry cv. Chandler. *Acta Horticulturae*, 696, 237-240.
DOI: <https://doi.org/10.17660/ActaHortic.2005.696.41>
3. Guardiola, J. L. and Garcia, L. (2000). Increasing fruit size in citrus by thinning and stimulation of fruit growth. *Plant Growth Regulation*, 31: 121-132.
4. Gupta, Ajeet, Tripathi, V.K. and Shukla J.K. (2022). Influence of GA₃, Zinc and Boron on Fruit drop, Yield and Quality of Litchi (*Litchi chinensis* Sonn.). *Biological Forum-An International Journal*, 14(3): 1079-1083.
5. Kumar, A., Tripathi, V. K., Dubey, V., Katiyar, N. K. and Tiwari, P. (2017). Influence of foliar application of calcium, zinc and boron on fruit drop, yield and quality attributes of aonla (*Emblica officinalis*) cv. NA-7. *Research on Crops*, 18 (1): 91-97.
6. Kumar, S. and Shukla, A.K. (2010). Improvement of old cv. Gola orchard through budding and micronutrients (Boron and zinc) management. *Indian Journal of Horticulture*, 67(3): 322-327.
7. Lal, D., Tripathi, V. K., Nayyar, A. M., Kumar, S., Ahmed, M. and Siddiqui, M. W. (2016). Pre-harvest Spray of GA, NAA and Calcium Nitrate on Fruit retention, Yield and Quality of Kinnow Mandarin. *Enviro. and Ecolo.*, 34 (4c): 2288-2292.
8. Meena, V.S., Yadav, P.K. and Singh, O.P. (2008). Yields attributes of Ber (*Zizyphus mauritiana* Lank.) cv. Gola as influenced by foliar application of ferrous sulphate and borax. *Agricultural Science Digest*, 28(3): 219-221.
9. Morton, J.F. (1960). Chemical analysis of the emblica (*Phyllanthus emblica* L.) and its potential as a food source. *Economic Botany*, 14(2): 119-128.
10. Raghava, M. and Tiwari, J.P. (1998). Effect of boron on growth, quality, and shelf-life of fruits of guava (*Psidium guajava* L.) cv. Saradar. *Progressive Horticulture*, 30 (1/2): 68-72.
11. Rajak, U., Rani, R., Kumar, R., Mandal, B.K. and Prasad, K.K. (2010). Effect of foliar application of urea, borax and zinc on flowering, fruiting, and fruit quality of mango (*Mangifera indica* L.) cv. Amrapali. *Environment and Ecology*, 28(3): 1668-1671.
12. Ruby, R. and Brahmachari, V.S. (2001). Effect of foliar application of calcium, zinc and boron on cracking and physico-chemical composition of litchi. *Orissa Journal of Horticulture*, 29(1): 50-54.
13. Saraswat, N.K., Pandey, U. N. and Tripathi, V. K. (2006). Influence of NAA and Zinc sulphate on fruit drop, cracking, fruit size, yield and quality of litchi cv. Calcuttia. *Journal of Asian Horticulture*, 2(4): 255-259.
14. Sharma, R.K., Kumar, R. and Thakur, S. (1993). Effect of foliar feeding of potassium, boron and zinc on yield and quality of guava. *Indian Journal of Horticulture*, 48 (4):312-314.
15. Shukla, H.S. and Verma, G. (2004). Effect of foliar application of NAA, potassium sulphate and zinc sulphate on fruiting and fruit characteristics of ber (*Zizyphus mauritana* Lamk.) cv. Banarasi Karaka. In Proceeding of International Seminar on Rec. Trend in Hi-tech and PHT, Organized by C.S.A.U.A.&T., Kanpur from Feb. 4-6: 167-168.
16. Shukla, H.S., Kumar, V. and Tripathi, V. K. (2011). Effect of gibberellic acid and boron on development and quality of aonla fruits 'Banarasi'. *Acta Horticulture*, 890: 375-380.
17. Singh, A. and Singh, H.K. (2015). Application of plant growth regulators to improve fruit yield and quality of Indian Gooseberry (*Emblica officinalis* Gaertn). *Journal of Agrisearch*, 2(1): 20-23.
18. Singh, A. K., Singh, P. P., Singh, S., Bhargava, R. and Makwana, P. (2016). Variability in morphological and physico-chemical traits of aonla (*Emblica officinalis*) genotypes collected from north-eastern region of India. *Indian Journal of Agricultural Sciences*, 86 (8): 992-997.
19. Singh, J. N., Singh, S. P. and Bahadur, L. (1989). Determination of maturity standards of aonla (*Emblica officinalis* Gaertn.) cultivars under eastern conditions of Uttar Pradesh. *Haryana Journal of Horticultural Sciences* 18: 216-20.
20. Singh, V. K. and Tripathi, V. K. (2010). Efficacy of GA₃, boric acid and zinc sulphate on growth, flowering, yield and quality of strawberry cv. Chandler. *Progressive Agriculture-An International Journal*, 10 (2): 345-348.
21. Sinha, A.K., Singh, C. and Jain, B.P. (1999). Effect of plant growth substance and micronutrients on fruit set, fruit drop, fruit retention and cracking of litchi cv. Purvi. *Indian Journal of Horticulture*, 56(4):309-311.

22. Tiwari, P., Tripathi, V.K. and Singh, A. (2017). Effect of foliar application of plant bio-regulators and micronutrients on fruit retention, yield and quality attribute of aonla. *Progressive Research-An International Journal*, **12**(4):2565-2568.
23. Tripathi, V.K. and Shukla, H.S. (2011). Influence of calcium chloride and calcium nitrate on physio-chemical composition of aonla 'Banarasi'. *Acta Horticulturae*, **890**: 371-374.
24. Tripathi, V.K. and Viveka Nand (2022). Effect of foliar application of Boron, Zinc and NAA on fruit retention, yield and quality attributes of aonla. *Progressive Horticulture*, **54** (1):76-81.
25. Tripathi, V.K., Pandey, S.S., Kumar, A., Dubey, V. and Tiwari, P. (2018). Influence of foliar application of gibberellic acid, calcium and boron on fruit drop, yield and quality attributes of aonla (*Emblica officinalis*) cv. NA 7. *Indian Journal of Agricultural Sciences*, **88** (11): 1784–88.
26. Verma, R.S., Singh, P.C. and Chaturvedi, O.P. (2008). Effect of foliar spray of zinc and boron on the physical parameters of aonla fruit cv. Banarasi. *The Asian Journal of Horticulture*, **3**(2): 344-345.



RESPONSE OF INTEGRATED NUTRIENT MANAGEMENT ON THE ECONOMICS OF BROCCOLI (*BRASSICA OLERACEA* L. VAR. *ITALICA*) CV. PUSA KTS-1

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ABSTRACT

A field experiment was carried out during 2019-20 and 2020-21 at Horticulture Research Farm, Department of Horticulture, Chaudhary Charan Singh University Campus, Meerut (U.P) to find out the response of integrated nutrient management on economics of broccoli (*Brassica oleracea* L. var. *italica*) CV. Pusa KTS -1. In the study total number of twelve treatments were used *i.e.* T₁ (Control), T₂ (RDF 150:100:100 N.P.K), T₃ (Azospirillum @ 5 kg), T₄ (VC @ 10 t/ha), T₅ (80% NPK + Azospirillum @ 1 kg), T₆ (60% NPK + 2t/ha VC + Azospirillum @ 1 kg), T₇ (60% NPK + Azospirillum @ 2 kg), T₈ (60% NPK + 4 t/ha VC), T₉ (40% NPK + Azospirillum @ 3 kg), T₁₀ (30% NPK + 7t/ha VC), T₁₁ (20% NPK + Azospirillum @ 4 kg), T₁₂ (20% NPK + 8t/ha VC). All treatments were randomly distributed among the plots and uniformly replicated three times. Results indicated that maximum mean value of gross income Rs. 573615, net income Rs. 398860.5 and B:C ratio 3.27 were recorded under 60% NPK + 2t/ha VC + Azospirillum @ 1kg. However, the control treatment showed minimum values in term of all economic parameters.

Keywords: INM, NPK, Vermicompost, Biofertilizer, Economics, Broccoli.

INTRODUCTION

Broccoli (*Brassica oleracea* L. var. *italica*) cv. Pusa KTS -1” is an important cole group vegetable belongs to the family Brassicaceae. Broccoli has originated in the Mediterranean region. In tropical areas broccoli mainly grown as annual vegetable crop (10). Broccoli is a cool season crop which is grown during the month of October-December as *Rabi* season crop. United State America is the largest producer of broccoli in the world. In India, broccoli mainly cultivated in hilly areas of Jammu and Kashmir, Himachal Pradesh, Nilgiri Hills, Tamil Nadu and northern plains of India (2).

Broccoli is grown for its tender heads. Broccoli is a rich source of vitamins, minerals, and proteins. 100 g of edible portion of broccoli contains 3500 IU vitamin A, 137 mg vitamin C, 3.3% proteins, 80 mg calcium, 79 mg phosphorus and 17 mg iron. It is also a rich source of glucosinolate particularly glucoraphanin, the substance associated with reducing of cancer (4). Broccoli has low content of carbohydrate, fat and dietary fibre.

Nutrients play a vital role in the growth and development of vegetable crops with good quality produce and high production. However, current agriculture largely depends

on the high usages of chemical fertilizers which decline soil health continuously so overcome to such type of problem INM is a best way for sustaining soil productivity and crop production. The most useful advantage of integrated use of inorganic and organic sources of fertilizers generally superior over use of each component separately. Integration of chemical fertilizers with organic manures had maintained long time fertility and sustains higher productivity (1). (9) reported that integrated nutrient management practices are more economical in terms of crops yield, gross income, net return and B: C ratio under different cropping systems. Hence, the present investigation was carried out to find out the response of integrated nutrient management combinations to enhance the yield and economic benefits in broccoli cultivation under western Uttar Pradesh condition.

MATERIALS AND METHODS

The present experiment was conducted during 2019-20 and 2020-21 at Horticulture Research Farm, Department of Horticulture, Chaudhary Charan Singh University Campus, Meerut (U.P.). Randomized block design with three replications was used for the experimental study. A total number of twelve treatments i.e. T₁ (Control), T₂ (RDF 150:100:100 N.P.K), T₃ (Azospirillum @ 5 kg), T₄ (VC @ 10 t/ha), T₅ (80% NPK + Azospirillum @ 1 kg), T₆ (60% NPK + 2t/ha VC + Azospirillum @ 1 kg), T₇ (60% NPK + Azospirillum @ 2 kg), T₈ (60% NPK + 4 t/ha VC), T₉ (40% NPK + Azospirillum @ 3 kg), T₁₀ (30% NPK + 7t/ha VC), T₁₁ (20% NPK + Azospirillum @ 4 kg), T₁₂ (20% NPK + 8t/ha VC) were used for the experimental study. Farm yard manure applied ten days before transplant of seedlings and properly mixed in the soil while vermicompost and biofertilizers (Azospirillum) were mixed in soil 2-3 days before transplanting. In case of inorganic

fertilizers (NPK), half doses of nitrogen and full dose of phosphorus and potash, were applied as a basal dressing at the time of transplanting. The remaining dose of nitrogen (N) was applied in two split doses i.e. 30 and 60 days after transplant of seedlings. Thirty days old, healthy and uniform seedlings of broccoli cv. Pusa KTS- 1 were subjected to transplant in the main field as per the layout plan during second week of October in two successive years i.e., 2019-20 and 2020-21. All needed practices such as weeding, irrigation and plant protection measures were adopted timely to ensure healthy crop production.

Average head yield (q/ha) was recorded during both the years of investigation. The cost of cultivation worked out by taking all the considerations of expenditure incurred on the basis of existing market rates of inputs. Gross income was calculated by multiplying per hectare yield of broccoli under various treatments with prevailing selling rates of broccoli in the local market. For calculating net profit in each treatment, cost of cultivation was subtracted from gross income. B: C ratio was worked out by dividing the net return of a treatment by the expenditure incurred.

RESULTS AND DISCUSSION

The data related to the effect of integrated nutrient management on economics of broccoli cultivation recorded during 2019-20 and 2020-21 are presented in table-1. In the present investigation, among all the integrated nutrient management (INM) treatments maximum yield (190.55 q/ha) was recorded under T₆ (60% NPK + 2t/ha VC + Azospirillum @ 1 kg). The economics of the broccoli were affected by different integrated nutrient treatment combinations. Maximum cost of cultivation (Rs. 174754.5/ha) was recorded under the soil application of 60% NPK + 2t/ha VC + Azospirillum @ 1 kg/ha followed by 80% NPK + Azospirillum @ 1 kg (Rs. 173205.5/ha) and 60% NPK +

Azospirillum @ 2 kg (Rs. 172169.5/ha). It might be due to high rate of chemical fertilizers, vermicompost and azospirillum and labour cost for their application in soil as per treatment. The minimum cost of cultivation (Rs.152461/ha) recorded under control treatment in which fertilizers and manures were not applied but fixed costs for cultivation were calculated. Similarly, the highest gross income (Rs.573615 /ha) was found under T₆ (60% NPK + 2t/ha VC + Azospirillum @ 1 kg) followed by 80% NPK + Azospirillum @ 1 kg (Rs.551850). The least value of gross income was recorded under T₁ (control). Gross income is directly related to the total production and market price of commodity. The present findings also similar to the findings of Wani *et al.* (2011), Mahapatra *et al.* (2013) and Mohanta *et al.* (2015).

The maximum net return (Rs.398860.5/ha) was recorded under treatment T₆ (60% NPK + 2t/ha VC + Azospirillum @ 1 kg) followed by 80% NPK + Azospirillum @ 1 kg

(Rs.378644.5/ha). However, minimum net return (Rs. 131549/ha) was obtained under T₁ (control). The maximum net return under soil application of 60% NPK + 2t/ha VC + Azospirillum @ 1 kg might be due to the high production with good quality produce which fetched high price from the market as compared to other treatments. The present findings also similar to the findings of Srichandan *et al.* (2010), Wani *et al.* (2010), Mohanta *et al.* (2015) and Negi *et al.* (2015). The benefit: cost ratio ranged from 1.87 to 3.27 and 1.86 to 3.28 during 2019-20 and 2020-21, respectively. The maximum B:C ratio (3.27 and 3.28) was noted under T₆ (60% NPK + 2t/ha VC + Azospirillum @ 1 kg) followed by 3.17 & 3.19 with the treatment T₅ (80% NPK + Azospirillum @ 1 kg). However, minimum benefit: cost ratio 1.87 and 1.86 was recorded under control during both the years of investigation, respectively. The main reason of higher gross income, net return and B: C ratio might be due to the soil application of NPK with vermicompost and biofertilizers resulted

Table 1. Response of integrated nutrient management on economics of treatments during 2019-20 and 2020-21.

Notation	Treatments	Total cost of cultivation (Rs./ha)			Head yield (q/ha)			Gross income (Rs./ha)			Net return (Rs./ha)			Benefit: Cost ratio		
		2019- 20	2020- 21	Mean	2019- 20	2020- 21	Mean	2019- 20	2020- 21	Mean	2019- 20	2020- 21	Mean	2019- 20	2020- 21	Mean
T ₁	Control (Absolute)	152280	152642	152461	94.52	94.15	94.33	283560	284460	284010	131280	131818	131549	1.87	1.86	1.86
T ₂	RDF (150:100:100) NPK	168532	168810	168671	165.46	165.10	165.28	496500	494880	495690	327968	326070	327019	2.94	2.93	2.93
T ₃	Azospirillum @ 5 kg	167920	168265	168092.5	176.65	176.28	176.47	529950	532260	531105	362030	363995	363012.5	3.15	3.16	3.15
T ₄	VC @ 10 t/ha	166615	166965	166790	126.20	125.81	126.01	378600	377910	378255	211985	210945	211465	2.27	2.16	2.21
T ₅	80% NPK + Azospirillum @ 1 kg	173101	173310	173205.5	183.40	182.82	183.11	550200	553500	551850	377099	380190	378644.5	3.17	3.19	3.18
T ₆	60% NPK + 2t/ha VC + Azospirillum @ 1 kg	174523	174986	174754.5	190.68	190.41	190.55	572040	575190	573615	397517	400204	398860.5	3.27	3.28	3.27
T ₇	60% NPK + Azospirillum @ 2 kg	172011	172328	172169.5	175.53	175.15	175.34	526590	527730	527160	354579	355402	354990.5	3.06	3.06	3.06
T ₈	60% NPK + 4t/ha VC	171110	171520	171315	172.42	172.05	172.24	517260	514830	516045	346150	343310	344730	3.01	3.00	3.00
T ₉	40% NPK + Azospirillum @ 3 kg	169688	169992	169840	170.40	170.03	170.22	511110	511620	511365	341422	341628	341525	3.01	3.00	3.00
T ₁₀	30% NPK + 7t/ha VC	167121	167425	167273	131.35	130.98	131.17	394050	397620	395835	226929	230195	228562	2.35	2.37	2.36
T ₁₁	20% NPK + Azospirillum @ 4 kg	165780	166971	166375.5	120.67	120.28	120.48	361980	364320	363150	196200	197349	196774.5	2.18	2.18	2.18
T ₁₂	20% NPK + 8t/ha VC	164245	164526	164385.5	115.72	115.35	115.54	348180	351930	350055	183935	187404	185669.5	2.11	2.13	2.12

continuous supply of plant nutrient to the plants during growth and at different developmental stages which helps in enhanced the crop yield. The present findings also similar to the findings of (8), (12) and (6).

REFERENCES

1. Bhardwaj, M.L., Raj, H. and Koul, B.L. (2000). Yield response and economics organic sources of nutrients as substitute to inorganic sources in tomato (*Lycopersicon esculentum*), Okra (*Hibiscus esculentus*), cabbage (*Brassica oleracea* var. capitata) and cauliflower (*Brassica oleracea* var. botrytis). *Indian Journal of Agricultural Sciences*, 70 (10): 653-656.
2. Chadha, K.L. (2001). "Handbook of Horticulture" Directorate of information and publications of Agriculture, ICAR, New Delhi.
3. Mahanta, R., Nandi, A.K., Mishra, S.P., Pattnaik, A., Hossain, M.M. and Padhiary, A.K. (2018). Effects of integrated nutrient management on growth, yield, quality and economics of sprouting broccoli (*Brassica oleracea* var. italica) cv. Shayali. *Journal of Pharmacognosy and Phytochemistry*, 7(1): 2229-2232.
4. Maurya, A.K., Singh, M.P., Srivastava, B.K., Singh, Y.V., Singh, D.K., Singh, S. and Singh, P.K. (2008). Effect of organic manures and inorganic fertilizers on growth characters, yield and economics of sprouting broccoli cv. Fiesta. *Indian Journal of Horticulture*, 65(1): 116-118.
5. Mohanta, R., Nandi, A.K., Mishra, S.P., Pattnaik, A., Hossain, M.M. and Padhiary, A.K. (2015). Effects of integrated nutrient management on growth, yield, quality and economics of sprouting broccoli (*Brassica oleracea* var. italica) cv. Shayali. *Journal of Pharmacognosy and Phytochemistry*, 7(1): 2229-2232.
6. Mohapatra, S.K., Munsu, P.S. and Mahapatra, P.N. (2013). Effect of integrated nutrient management on growth, yield and economics of broccoli (*Brassica oleracea* var. italica Plenck). *Vegetable Science*, 40(1): 69-72.
7. Negi, E., Punetha, S., Pant, S.C., Sandeep, K., Pankaj, B., Bengia, M. and Nautiyal, B.P. (2015). Effect of organic manures and bio-fertilizers on growth, yield, quality and economics of broccoli (*Brassica oleracea* L. var. italica plenck) cv. Green head under high-hill conditions of Uttarakhand. *International Journal of Advances in Biology*, 7(1): 96-100.
8. Srichandan, S., Mangaraj, A.K.U., Mohanty, A., Behera, K.K. and Panda, D. (2010). Influence of organic and inorganic fertilizer on nutrient content in broccoli (*Brassica oleracea* var. italica). *Plant Archives*, 15(2): 1127-1130.
9. Srinivasarao, C., Naik, M.R., Lakshmi, C.S., Kumar, R., Manasa, R., Rakesh, S., Kundu, S. and Prasad, J.V.N.S. (2020). Economic and environmental effect of integrated nutrient management in Indian Agriculture. *Indian Journal of Fertilisers*; 16(11): 1124-1137.
10. Thamburaj, S. and Singh, N. (2001). Vegetables, tuber crops and spices. Directorate of information and publications of Agriculture, ICAR, New Delhi.
11. Wani, A.B.J., Narayan, R., Ahmed, N., Singh, A.K., Chattoo, M.A. and Sumati, N. (2011). Influence of organic and inorganic sources of nutrients on growth, yield and quality of cauliflower (*Brassica oleracea* L. Var. botrytis). *Environment and Ecology*, 29(4A): 1941-1947.
12. Wani, A.J., Mubarak, T. and Rather, G.H. (2010). Effect of organic and inorganic nutrient sources on growth and curd yield of cauliflower (*Brassica oleracea* L. var. botrytis) cv Snowball-16. *Environment and Ecology*, 28 (3): 1660-1662.



INFLUENCE OF ROOT DIPPING APPLICATION AS STARTER SOLUTION ON QUALITY AND NUTRIENT UPTAKE OF CHILLI (*CAPSICUM ANNUUM* L.)

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ABSTRACT

An experiment was conducted at PG Department of Agriculture, Khalsa College, Amritsar during the year 2022-23 to find out the influence of urea solution application as root dipping on chilli quality and nutrient uptakes. The treatments were comprised of one control N₁ (water dip only) and three concentrations of urea solution *viz.*, N₂ (1% urea solution), N₃ (2% urea solution) and N₄ (3% urea solution) applied as root dip to one chilli hybrid *i.e.*, G₁ (Arka Gagan) and one variety namely G₂ (Kashi Anmol). All the treatments were laid out in Factorial Randomized Block Design (FRBD) with three replications. The results of the study revealed that all the quality parameters such as plant dry matter, fruit dry matter and Vitamin C content in fresh fruit were found to be declined with increased concentration of urea solution. Whereas, the uptake of nitrogen as percentage in leaves and fruits of chilli plant was found to be improved with increased concentration of urea solution.

Keywords: Chilli quality. Root dipping. Nitrogen content. Starter solution. Urea

INTRODUCTION

Among Solanaceous crops, Chilli is the most important crop grown for its fresh consumption as vegetable and also as spice crop. Chilli is cultivated on an area of 20.9 lakh ha in the world with an annual production of 36.2 million tonne (2). India is the largest consumer, producer and exporter of chilli in the world (16). The chilli was grown on an area of 4.3 lakh ha with production of 4.7 million tonne in India (3). The chilli productivity (8.4 tonne/ha) in India is very low as compared to world's (36.2 tonne/ha) and Nepal (9.5 million/ha). There are various

factors *i.e.*, plant population, environmental, pest and disease attack, soil fertility and improper fertilizer management etc. that affects the yield and quality potential of chilli (8). Among these, the fertilization is the most important factor that effects quality production of chilli (6, 14).

Application of fertilizers in solution form applied to the root zone has been found to be significantly influence the quality parameters of vegetables. AVRDC (2004) conducted several experiments and reported that the application of inorganic fertiliser in the form of a starter solution significantly increased the

plant dry weight and NPK uptake of the vegetable crop. Dry matter production of the leafy vegetable was increased with increasing nitrogen availability (25). It was reported that the increasing urea solution from 0.4 to 1.0% reduced the quality of broccoli (dry matter, chlorophyll, vitamin C) (27). The application of nitrogen fertilizer decreased the Vitamin C content at both market maturity and fruiting stages of the plant development (15). The highest total soluble solids content was recorded under treatment combination where highest dose of nitrogen was applied to tomato crop (13). (9) revealed that nutritional quality (total phenols, vitamin C and dry matter of head) of cabbage was significantly influenced with starter fertilizer with respect to control treatments. The maximum ascorbic acid (118.67 mg/100g) and TSS (6.75 °Brix) was recorded with application of highest dose of fertilizers in liquid form applied near root area of capsicum (12). It was observed that providing nutrition at early stage helps to increase the quality (percentages of dry matter, starch and phenols) as compared to control (7). Applications of water soluble NPK fertilizers improved TSS, titratable acidity, Electric conductivity, vitamin C as compared to control treatment in tomato (4). Therefore, an experiment was planned to find out the effect of starter solution applications on quality and nutrient uptake of chilli crop.

Materials and Methods

Experimental site

The present investigation entitled “Influence of root dipping application as starter solution on quality and nutrient uptake of chilli (*Capsicum annuum* L.)” was conducted at experimental Vegetable Research Farm, P.G. Department of Agriculture, Khalsa College, Amritsar during 2022-2023. Before the field preparation, soil samples of the experimental field were collected and analysed for various parameters

that are shown in Table 1.

Planting materials

The seeds of hybrid Arka Gagan were procured from IIHR, Bangalore, Karnataka and variety Kashi Anmol from IIVR, Varanasi, Uttar Pradesh, India. The seeds were sown in plug trays filled with a soilless mixture of cocopeat, perlite and vermiculite (3:1:1) during the second fortnight of October in the year, 2022.

Experimental methodology

The urea solutions of different concentration *i.e.* 1%, 2 % and 3 % were prepared by dissolving the required amount of urea fertilizer (46% N) per litre of water. The control treatment was kept as water dip only (0% urea solution). Before transplanting the seedlings at the age of thirty five days, the seedlings were uprooted from the plug trays and growing medium was removed by shaking or slightly hitting to ground. The seedling roots of both Arka Gagan and Kashi Anmol were dipped into urea containing solutions. The treated seedlings were planted on one side of the ridges at a spacing of 75 cm × 45 cm. The field was slightly irrigated just after transplanting. The experiment consisted of eight treatments replicated thrice that were laid out in factorial randomised block design. There were fifteen plants transplanted in each treatment per replication. The whole experiment was performed under low tunnel technology to save the seedlings from frost till the middle of February. All the package and practices were followed for raising a good crop as per given in the book prepared by Punjab Agricultural University, Ludhiana (1).

Observations recorded

The data for different plant parameters were determined from six randomly selected plants in each replication per treatment and the average was calculated. The data was collected as follows;

Quality parameters

Ascorbic acid content (mg/ 100gm)

Among quality parameters ascorbic acid content was estimated by using “2,6 dichlorophenol-indophenol visual titration method” as described by Ranganna (1979).

Dry matter (%)

The fresh fruit sample of 50 g was cut in to pieces and taken in previously weighed petri dish and dried in an oven at 65°C. For plant dry weight, the six tagged plants from each plot were uprooted from the field after harvest and their fresh weight was recorded. These samples were then dried in oven at 65°C. The weight of plants was taken when they are fully dried and average was calculated. The dry matter % of fruit as well as plant was calculated as:

$$\text{Dry matter percentage} = \frac{\text{Final dry weight of sample}}{\text{Original fresh weight of sample}} \times 100$$

Determination of Nitrogen in leaves and fruit samples of chilli

Nitrogen (%)

Samples of fruits were taken at random from each treatment at 75 and 105 days after transplanting. The leaf samples were taken at random from each treatment at 45, 75 and 105 days after transplanting for nitrogen analysis. Nitrogen (%) of leaves as well as fruits was analysed by Kjeldahl's method (20).

Total Nitrogen uptake (Kg/ha)

Dry matter (Kg/ha) of fruits was calculated by multiplying the dry matter (%) in fruits with fruit yield per hectare. Similarly, dry matter (Kg/ha) of plants was calculated by multiplying dry matter (%) of plant with total number of plants per hectare. Further, nitrogen uptake by fruits and plants was individually calculated by using following formula;

$$\frac{\text{Total nitrogen uptake (Kg/ha)}}{\text{Nitrogen concentration (\%)}} \times \frac{\text{Dry matter (kg /ha)}}{100}$$

The nitrogen uptake by fruits and nitrogen uptake by plants was summed up to calculate total nitrogen uptake (Kg/ha)

Statistical analysis

The data pertaining to the present investigation were statistically analysed at the 5% level of significance using OPSTAT software (22).

Results and Discussion

Quality parameters

The maximum plant and fruit dry matter (46.96% and 17.76%) and ascorbic acid (50.25 mg/100g) was observed under 0% starter solution where no urea was applied and the minimum plant and fruit dry matter (25.42% and 10.13%) and ascorbic acid (48.20 mg/100g) was observed under 3% starter solution where highest concentration of urea was applied (Table 2). The result revealed that the dry matter content was reduced with increasing concentration of urea solution. It could be due to the reason that increased nitrogen content within leaves and plant tissues replaced the organic acids and sugars with nitrates (21). Our findings were consistent with those of (19), who discovered that increasing nitrogen fertiliser led to a decrease in dry matter content in broccoli. Similarly, increased production of protein due to high nitrogen reduces the synthesis of carbohydrates that ultimately decreased the production of vitamin C (26). Our results are conformity with those of Sorensen (1999) who also observed the decrease in ascorbic acid with increase in nitrogen application.

For the different genotypes, significant maximum plant dry matter (35.37%) was recorded in genotype Arka Gagan while maximum ascorbic acid (39.05 mg/100g) was

recorded in genotype Kashi Anmol whereas fruit dry matter was observed non-significant.

For the interaction between genotypes and starter solution, significantly maximum plant dry matter (48.58%) was observed under treatment G_1N_1 i.e. Arka Gagan applied with water dip only whereas, fruit dry matter and ascorbic acid content was found non-significant.

Nutrient uptake

Significantly highest nitrogen concentration at different days in leaves and fruits and maximum nitrogen use efficiency (36.10%) was observed under 3% starter solution while total nitrogen uptake (230.26) was found highest under control (Table 3). Minimum nitrogen concentration at different days interval in leaves and fruits and nitrogen use efficiency was observed under control where no urea solution was applied as root dipping whereas total nitrogen uptake was observed minimum under 3% starter solution.

Increasing N application increased plant tissue nitrogen concentration in both years for pepper and tomato plants (17). (10) reported increasing nitrogen level from 75 to 225 Kg N/ha, the nitrogen concentration was also increased in bitter gourd. (11) also observed similar result of accumulation of higher nitrogen in tomato with higher dose of nitrogen. For nitrogen use efficiency, our findings contradict with the findings of Du *et al.* (2017) and (11), who reported that adding nitrogen reduces the nitrogen usage efficiency of tomato. Similar result of decreasing total nitrogen uptake in chilli with increasing dose of nitrogen was observed by (23).

Among different genotypes, maximum nitrogen concentration in leaves (5.25%) founds significantly only at 75 DAP and in fruits (4.33%) founds significant only at 105 DAP in genotype Kashi Anmol. Total nitrogen uptake and nitrogen use efficiency was found non-significant. Interaction effect for nutrient uptake studies was also found non-significant.

Table 1 Soil analysis

S.No.	Particulars	Level/content
i.	Soil pH	8.49
ii.	Organic carbon (%)	0.47
iii.	Electrical Conductivity (mmhos/cm)	0.17
iv.	Available Nitrogen (Kg/ha)	326
v.	Available Phosphorus (Kg/ha)	9.34
vi.	Available potash (Kg/ha)	207.71

Table 2 Effect of starter solution application on quality parameters of chilli

Treatments	Plant dry matter (%)	Fruit dry matter (%)	Ascorbic acid (mg/100g)	
Genotypes	G_1 (Arka Gagan)	35.37 ^a	12.98	39.05 ^b
	G_2 (Kashi Anmol)	30.82 ^b	13.03	59.32 ^a
	CD (p= 0.05)	1.44	N/S	0.34
	SE(m)	0.47	.52	0.11
Urea solution	N_1 (0% urea solution)	46.96 ^a	17.76 ^a	50.25 ^a
	N_2 (1% urea solution)	32.09 ^b	12.70 ^b	49.56 ^{ab}
	N_3 (2% urea solution)	27.92 ^c	11.43 ^{bc}	48.75 ^b
	N_4 (3% urea solution)	25.42 ^d	10.13 ^c	48.20 ^c

	CD (p= 0.05)	2.04	1.87	0.48
	SE(m)	0.66	0.61	0.15
Interaction	Genotype × Urea solution			
	G ₁ N ₁	48.58 ^a	17.26	40.26
	G ₁ N ₂	36.84 ^c	13.06	39.53
	G ₁ N ₃	29.21 ^c	11.73	38.50
	G ₁ N ₄	26.86 ^d	9.86	37.93
	G ₂ N ₁	45.35 ^b	18.26	60.23
	G ₂ N ₂	27.35 ^{de}	12.33	59.60
	G ₂ N ₃	26.63 ^e	11.13	59.00
	G ₂ N ₄	23.98 ^e	10.40	58.46
	CD (p= 0.05)	2.89	N/S	N/S
	SE(m)	0.94	0.86	0.22

Table 3 Effect of starter solution on nutrient uptake by chilli

Treatments	Nitrogen uptake						
	Leaves %	Fruits %	Total uptake (Kg/ha)				
	45 DAT	75 DAT	105 DAT	75 DAT	105 DAT		
Genotypes	G ₁ (Arka Gagan)	5.21	4.88 ^b	3.66	2.81	4.29 ^b	193.55
	G ₂ (Kashi Anmol)	5.11	5.25 ^a	3.75	2.92	4.33 ^a	178.62
	CD (p= 0.05)	N/S	0.10	N/S	N/S	0.03	N/S
	SE(m)	0.04	0.03	0.03	0.03	0.01	5.44
Urea solution	N ₁ (0% urea solution)	4.91 ^d	4.86 ^d	3.38 ^d	2.58 ^d	4.16 ^d	230.26 ^a
	N ₂ (1% urea solution)	5.04 ^c	4.98 ^c	3.65 ^c	2.81 ^c	4.28 ^c	178.11 ^b
	N ₃ (2% urea solution)	5.25 ^b	5.13 ^b	3.81 ^b	2.95 ^b	4.37 ^b	170.73 ^b
	N ₄ (3% urea solution)	5.43 ^a	5.30 ^a	3.98 ^a	3.12 ^a	4.43 ^a	165.25 ^b
	CD (p= 0.05)	0.17	0.14	0.17	0.15	0.05	23.56
	SE(m)	0.05	0.04	0.05	0.05	0.01	7.69
Interaction	Genotype × Urea solution						
	G ₁ N ₁	5.01	4.66	3.30	2.51	4.12	230.54
	G ₁ N ₂	5.14	4.76	3.60	2.78	4.27	191.31
	G ₁ N ₃	5.27	4.93	3.83	2.87	4.35	182.13
	G ₁ N ₄	5.43	5.16	3.93	3.11	4.41	170.22
	G ₂ N ₁	4.80	5.06	3.46	2.66	4.20	229.97
	G ₂ N ₂	4.95	5.20	3.70	2.84	4.29	164.91
	G ₂ N ₃	5.24	5.33	3.80	3.04	4.38	159.33
	G ₂ N ₄	5.44	5.43	4.03	3.13	4.44	160.27
	CD (p= 0.05)	N/S	N/S	N/S	N/S	N/S	N/S
	SE(m)	0.08	0.06	0.07	0.07	0.02	10.88

Conclusion

The quality parameters such as plant dry matter (%), fruit dry matter (%) and ascorbic acid (mg/100g) were found to be declined with the increasing concentration of urea. While, the percentage of nitrogen content in leaves as well as in fruit was found to be improved with the increased concentration of urea solution (3% urea solution).

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References

1. Anonymous (2021). Package of Practices for Cultivation of Vegetables. Punjab Agricultural University, Ludhiana.
2. Anonymous (2021a). Area and production of chilli in the World. Horticulture Statistics at a glance. Food and Agriculture Organization, Rome, Italy. Retrieved from <https://www.indiastat.com>. accessed on 13 September, 2023.
3. Anonymous (2023). Area and production of chilli in India. *Ministry of Agriculture and Farmer welfare, Government of India*. Retrieved 13 September, 2023, from <https://www.indiastat.com>.
4. Ashraf, M., Shaukat, M.B., Liaqat, B., Kiran, S., Khalid, W., Anam, L., Kaleem, Z. and Abdullah, M. (2021). Effect of foliar application of water-soluble fertilizer on growth, yield and quality attributes of tomato (*Solanum lycopersicum* Mill.). *International Journal of Agronomy and Agricultural Research*, **18(1)**: 10-18.
5. AVRDC (2004). Progress reports 1998-2003. Asian Vegetable Research and Development Center, Shanhua, Taiwan.
6. El-Afifi, S.T., Zaghloul, M.M., El-Sawy, M.B.I. & Hashim, A.M.A. (2014). Effect of starter solutions in soil and foliar spray with some stimulants on growth and productivity of Chinese cabbage. *Journal of Plant Production*, **5(1)**, 21-40. <https://doi.org/10.21608/JPP.2014.53311>.
7. Feleafel, N.M., Abd El-Kader, Y.D. and Shimaa, M.H. (2019). Minimizing NPK fertilizers by using starter fertilizers and enhancing nutritional quality of potato. *Journal of Horticultural Science and Ornamental Plants*, **11(3)**: 214-221.
8. Gade, P.A., More, S.S., Shelke, R.D. & Nalegaonkar, A.R. (2020). Growth and instability in area, production and yield of chilli in India. *International Journal of Current Microbiology and Applied Sciences*, **9(11)**, 2647-2654. <https://doi.org/10.20546/ijcmas.2020.911.321>.
9. Hassan, S.M.R. and Qadar Y.D.M. (2016). Influence of Starter Fertilizer and Calcium Nitrate Rates on Vegetative Growth, Yield and Nutritional Quality of Cabbage. *Alexandria Science Exchange Journal*, **37**: 811-819.
10. Heidari M. & Mohammad M. M. (2012). Effect of rate and time of nitrogen application on fruit yield and accumulation of nutrient elements in *Momordica charantia*. *Journal of the Saudi Society of Agricultural Sciences*, **11(2)**, 129-33. <http://dx.doi.org/10.1016/j.jssas.2012.02.003>.
11. Jalpa L., Mylavarapu, R.S., Hochmuth, G., Wright, A. & Santen, E.V. (2021). Recovery efficiency of applied and residual nitrogen fertilizer in tomatoes grown on sandy soils using the ¹⁵N technique. *Scientia Horticulturae*, **278**, 1-8. <https://doi.org/10.1016/j.scienta.2020.109861>.
12. Kaur, R., Singh, S.K. and Raturi, H.C. (2017). Effect of different levels of fertigation and foliar application of nutrients on capsicum (*Capsicum annuum* L. var. grossum) grown in soilless media under polyhouse conditions. *Journal of Pharmacognosy and Phytochemistry*, **6(6)**: 1770-1773.
13. Kumar, M., Meena, M.L., Kumar, S., Maji, S., and Kumar, D. (2013). Effect of nitrogen, phosphorus and potassium fertilizers on the growth, yield and quality of tomato var. Azad T-6. *The Asian Journal of Horticulture* **8(2)**: 616-619.
14. Mahmud, K., Hossain, T., Haque Mou, T., Ali, A. & Islam, M. (2020). Effect of nitrogen on growth and yield of chili (*Capsicum annuum* L.) in Roof Top Garden. *Turkish Journal of Agriculture - Food Science and Technology* **8(1)**, 246-251. <https://doi.org/10.24925/turjaf.v8i1.246-251.2763>.
15. Musa, A., Ezenwa, M.I., Oladiran, J.A., Akanya, H.O. and Ogbadoyi, E.O. (2010). Effect of soil nitrogen levels on some micronutrients, antinutrients and toxic substances in *Corchorus olitorius* grown in Minna, Nigeria. *African Journal of Agricultural Research*, **5(22)**: 3075-3081.
16. Natarajan, A., Sahu, M., Srivastava, S.C. & Jaulkar, A.M. (2023). Study on cost of cultivation and economic returns from chilli crop growing districts of Telangana, India. *International Journal of Environment and Climate Change*, **13(9)**, 1592-1601. <https://doi.org/10.9734/ijecc/2023/v13i92391>.
17. Ortas I. (2013). Influences of nitrogen and potassium fertilizer rates on pepper and tomato yield and

- nutrient uptake under field conditions. *Scientific Research and Essays*, 8(23), 1048-1055. [https://DOI:10.5897/SRE11.579](https://doi.org/10.5897/SRE11.579).
18. Ranganna, S. (1979). *Manual of Analysis of Fruit and Vegetable Production*. Tata McGraw Hill, New Delhi.
 19. Roni, M.S., Zakaria, M., Hossain, M.M. & Siddiqui, M.N. (2014). Effect of plant spacing and nitrogen levels on nutritional quality of broccoli (*Brassica oleracea* L.). *Bangladesh Journal of Agricultural Research*, 39(3), 491-504.
 20. Sáez-Plaza, P., Navas, M.J., Wybraniec, S., Michałowski, T. and Asuero, A.G. (2013). An overview of the Kjeldahl method of nitrogen determination. Part II. Sample preparation, working scale, instrumental finish, and quality control. *Critical Reviews in Analytical Chemistry*, 43(4): 224-272. <http://dx.doi.org/10.1080/10408347.2012.751787>.
 21. Santamaria, P., Elia, A., Serio, F. & Todaro, E. (1999). A survey of nitrate and oxalate content in fresh vegetables. *Journal of the Science of Food and Agriculture*, 79(13), 1882-1888. [https://doi.org/10.1002/\(SICI\)1097-0010\(199910\)79](https://doi.org/10.1002/(SICI)1097-0010(199910)79).
 22. Sheoran, O.P., Tonk, D.S., Kaushik, L.S., Hasija, R.C. & Pannu, R.S. (1998). Statistical software package for agricultural research workers. Department of Mathematics Statistics, CCS HAU, Hisar, 8(12), 139-143.
 23. Singh. A. (2016). Water and nutrient use efficiency as influenced by drip fertigation in cauliflower and chilli. Ph. D Thesis, Maharana Pratap University of Agriculture and Technology, Udaipur, India.
 24. Sorensen, J.N. (1999). Nitrogen effects on vegetable crop production and chemical composition. *Acta Horticulture*, 506, 41-49. <https://doi.org/10.17660/ActaHortic.1999.506.4>.
 25. Suphachai, A., Takagaki, M., Chaireag, S., Sutevee, S. and Inubushi, K. (2006). Effect of amount of nitrogen fertilizer on early growth of leafy vegetables in Thailand. *Japanese Journal of Tropical Agriculture*, 50(3): 127-132.
 26. Worthington V. (2001). Nutritional quality of organic versus conventional fruits, vegetables, and grains. *The Journal of Alternative and Complementary Medicine*, 7(2), 161-173. <https://doi.org/10.1089/107555301750164244>.
 27. Yildirim, E., Guvenc, I., Turan, M. and Karatas, A. (2007). Effect of foliar urea application on quality, growth, mineral uptake and yield of broccoli (*Brassica oleracea* L., var. *italica*). *Plant Soil and Environment*, 53(3): 120.



STUDY ON NUTRITIONAL & MEDICINAL PROPERTIES OF LEMON

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ABSTRACT

Lemon (*Citrus limon*) is a widely cultivated fruit crop known for its distinct tangy flavour and numerous health benefits. This abstract explores the biological attributes of lemon, emphasizing its genetic, physiological, and ecological characteristics. Genetically, lemon belongs to Rutaceae family and a hybrid of the citron and lime, exhibiting a diverse array of cultivars adapted to various climates. Physiologically, lemon are characterized by their high citric acid content, which contributes to their acidity and preservative qualities. The fruit's composition includes a range of bioactive compounds such as vitamin C, flavonoids, and essential oils, which provide antioxidant, anti-inflammatory, and antimicrobial properties. Ecologically, lemon trees are adaptable to a range of soil types but thrive in well-drained soils with a Mediterranean climate. Their cultivation practices involve managing water stress and pest control to optimize fruit yield and quality. Understanding these biological attributes is crucial for enhancing lemon cultivation practices, improving fruit quality, and leveraging the health benefits associated with its consumption.

Citrus fruits are widely grown in the tropics and are incredibly nutritious and therapeutic. Ayurveda identifies therapeutic virtues in many sections of the lemon tree. Lemon has several qualities, including anti-inflammatory, antiviral, antioxidant, and anti-diabetic effects. This review examines many effects, including antifungal, anti-oxidant, anti-inflammatory, anticancer, antibacterial, anti-ulcer, and desorption properties. Lemon has a high concentration of key natural elements such as ascorbic acid, minerals, citric acid, essential oils, and flavonoids. Lemon has alkaloid constituents in its leaves, stem, root, and flower, which have anti-cancer and antibacterial properties. The Millennium Development Goals (MDGs) aim to combat ailments such kidney stones, respiratory disorders, cancer, blood sugar balance, and cardiovascular disease. Secondary metabolites are potential medication sources because of their medicinal value. These secondary metabolites are abundant in therapeutic plants.

Keywords: *Lemon. Nutritional, Medicinal, Phytochemicals etc.*

INTRODUCTION

Citrus limon (lemon) is a little evergreen tree native to Asia. There are several distinct kinds of lemon, and the fruit is yellow and

ellipsoidal. Following oranges and mandarins, it is the most significant citrus fruit species. The “term” lemon derives from the ancient French word “limon.” The terms “limone,”

Arabic “lamun” or “lmun,” and Persian “lmun” all have different names in Italy. The generic word ‘lime’ refers to citrus fruit and is related to Sanskrit nimbu. Lemon is a blooming plant from the Rosaceae family. The genus citrus has around 140 genes and 1300 species [9]. It originated in Southeast Asia and subsequently expanded to north-eastern India, Burma, and China. Citrus fruits have been grown all over the world since antiquity. The greatest sorts of lemons include Lisbon, Eureka, and Meyer. The Lisbon citrus tree range tolerates heat, cold, and windy conditions and, with adequate care, produces multiple plants per year. The lemon tree “Lisbon” is 30 feet long and has a 25-foot-wide canopy. The ‘Eureka’ grows all year round. It is also known as “Four Seasons” (Quarters seasons) since it may produce fruit and blooms throughout the year. The “Meyer” was named after Frank N. Meyer, who first introduced it to the United States in 1908 as a hybrid between lemons, maybe an orange or a mandarin. The tree is small, with lustrous, leathery, alternating, and mostly evergreen leaves containing oil glands. The stems are frequently winged and attached to the leaves most of the time. The scent of flowers is both intense and delicious. The fruit is spherical or shaped like an egg. It contains 8/14 juicy patches with large white or greenish seeds. Lemon has long been used as an addition to alleviate sore throats in our cuisine [14]. Citric acid and carboxylic acid are acidic substances found in lemon peel’s chemical makeup, together with water.

Lemon is the third most important citrus fruit after orange, with around 4.4 million tons produced annually. Argentina currently produces the most lemons in the world, at 1.2 million tonnes. Lemon contains many natural substances such as ascorbic acid, minerals, citric acid, essential oils, and flavonoids [10]. Lemon has alkaloid constituents in its leaves, stem, root, and flower, which contribute to its

anticancer and antibacterial properties [7]. There are several lemon cultivars, including Avon, Berna, Baboon, Bearss, and Cameron [12]. Lemon peels include phytochemicals including glycosides, volatile oils, and α and β -sitosterol. Lemons include significant activities such as polyethoxylated, ascorbic acid, flavones, and phenolic chemicals that are unique to other plants.

Herbal medications are commonly utilized in both developed and developing nations due to its natural nature and lack of adverse effects. Traditional remedies can be derived from medicinal plants. The World Health Organization (WHO) lists 21,000 medicinal plants used globally. The World Health Organization (WHO) recommends medicinal plants as the greatest source for acquiring a diverse range of medications. India, known as the world’s botanical garden, is the greatest producer of medicinal herbs [24]. Citrus, the most often used plant in traditional medicine. Citrus is native to Asia’s tropical and subtropical regions. Citrus fruits are commonly consumed in Mediterranean cuisine throughout the winter season. Citrus fruits are widely grown in the tropics and are known for their nutritional and therapeutic benefits.

Historical Events

The lemon plant was first introduced in southern Italy in 200 A.D., and it was then spread to Iraq and Egypt around 700A.D. Lemon was first spread in the Mediterranean region between 1000-1150 A.D. and later cultivated in China about 760-1297 A.D. In 1493, lemon was introduced to Spain and thereafter to Hispaniola Island. Lemon was launched in California from 1751 to 1786 [2].

Scientific description:

Citrus trees yield fruits in various forms and sizes (round to rectangular), are evergreen, and have a rich flavour, smell, and juice [16]. Lemon leaves are dark green,

6.5-10mm in size, and alternately placed on the stalk. Fresh shoots are typically formed in the near-end leaf axles during pre-spring or summer vegetative growth. In temperate climates, only two flushes happen every year, but in hotter, subtropical areas, three to five flushes occur. Tropical shoots often emerge continually throughout the year. The mid-summer and following flushes are typically vegetative, with fewer but longer shoots and larger leaves [17]. Lemon leaf blades are oval in form. The leaf morphology is determined by the tree's vitality. When the laminae develop, they turn green, while newly produced leaves remain purple. Most Citrus species, including the lemon, are tap-rooted. The root emerges at germination and soon expands into a well-defined taproot. Fibrous roots grow in little bunches 20-30 cm long on the taproots of young seedlings and pioneer roots of older plants. Branches from the primary root of the fibrous bunch are lower than the primary root and are further reduced by sub-branches from the primary branches. The blooms in ripe citrus are 1.5-3 cm long and have a pedicel. The cup with five sepals is comparable to a calyx. Interlocking marginal papillae form the petals, which are thick and dazzling enough to reflect on. The stamens have 20-40 partially joined filaments, each with a yellow, four-lumped anther. Others encircle the pistil at the stigma. The floral disk produces the stomach from liquid nectar. The ovary is sub globous, as opposed to a tight form like orange or sub cylindric, with a fusion in the fashion of citrus. The pistil consists of 8-14 carpet ovaries. Lemon blossoms are large and immaculate, with the same general characteristics as other commercial citrus species. Purple white flowers have petals. The edible fruit section, the pericarp, is referred to as the rind or peel, and the endocarp as the pulp. The colourful regions of the flavedo on the surface are epicarp, also known as flavedo, and the white layer on the interior is mesocarp, also known as albedo, this

distinction is also visible within the peel. The flavedo is made up of a cuticular-covered epidermis and several adjacent compact parenchyma cell layers. The flavedo is full of essential oils. Essential oils are often described by GC-MS analysis [3,8,19]. Lemon pulp is very acidic, with bisexual and male flowers. 'Pink Lemonade' is a lemon cultivar that gives rise to lemon flowers. This cultivar produces striped fruit and variegated foliage. Lemons often have an oval shape and a smooth, spongy surface [25].

Phytochemicals and nutrition's values:

Phytonutrients demonstrate the biological link between plants and human health. Phytonutrients are plant-derived bioactive substances that benefit humans. Lemon is among the citrus fruits with high phytoconstituent content. Citrus fruits include flavonoids, coumarins, and volatile oils [1]. Citrus fruit contains flavonoids, glycosides, coumarins, and sitosterol. Citrus fruits account for only 0.9% of total daily calories and 1.7% of daily carbs. Polyethoxylated flavones are highly important and uncommon in other plants. Citrus fruit fibre includes bioactive compounds like polyphenols, including vitamin C (ascorbic acid), which can help treat vitamin C deficiencies. According to Hashemipour *et al.* (2016), vitamin B6 is 0.080 mg (6%), niacin is 0.100 mg (1%), and folate is 11 µg (3%). It has high levels of carotenoids, vitamin C (which can convert to vitamin A), fibre, and folate. Citrus oils include a high concentration of mono-terpene hydrocarbons (70.95%) and less sesquiterpene hydrocarbons, which contribute to its distinct flavour [1].

Postharvest technology:

Lemons are collected according to the weather. The three main varieties of lemons, "Eureka," "Lisbon," and "Meyer," each have their own harvest season. Lemons are ready to be picked when they appear yellow or yellow

green and firm. The fruit measures 2 to 3 inches. Waiting for the right size and not worrying too much about hue is preferable to expecting them to be completely yellow. Citrus fruit that is ready to pluck is also moderately brilliant. Citrus like to make decisions early rather than late. Lemons that are yellow-green in colour will most likely ripen off the tree. If they are squishy, you have waited too long. It is not difficult to pick lemons off a tree if you do not injure the tree [4].

Uses in medicine:

Lemon juice is used to heal the plague and make acridine citri, a syrup that quenches thirst. It is also a source of conflict. Honey is cooked with lemon and used as a digestive. It is also useful to remove pimples and black spots from the face [22].

Lemon juice was used to treat intestinal worms and remove kidney stones and gravel [5]. Drinking citrus juices has been shown to reduce oxidative stress, prevent atherogenic changes in LDL cholesterol, improve blood lipid profile, platelet aggregation, and increase HDL cholesterol concentrations. The extract has been shown to have anti-thyroidal effects, indicating promise for treating hyperthyroidism [22].

Citrus fruits have comparable phytonutrient content, making them both nutritious and therapeutic. Citrus is the major source of vitamin C1 for primates. Ascorbic acid enhances iron absorption from the small intestine and is essential for connective metabolism, including scar tissue, teeth, and bones. It provides stress relief and protects against colds and chills. It protects against free radicals caused by UV radiation and acts as an antioxidant for the skin [16].

Collagen formation is also dependent on vitamin C. Collagen promotes skin rejuvenation and improves fine wrinkles. Extracts of d-limonene enhance the amount of protein and energy constituents in the body,

leading to a rise in protein serum levels. Citrus fruits and peels can improve metabolic and inflammatory illnesses due to their richness of bioactive chemicals [20].

Pharmacological Properties:

Citrus species have been identified for their physiological, therapeutic, and pharmacological actions, including antioxidant, anti-inflammatory, hypoglycaemic, anticancer, and antibacterial properties. Consuming the primary constituent of C. limon essential oil, D-limonene, at concentrations of 0.5% and 1.0%, has been demonstrated to have a significant relaxing and anxiolytic impact on rats via activating serotonin and dopamine receptors [23]. C. limon has high pharmacological potential due to its diverse chemical composition. Fruit contains several secondary metabolites, including flavonoids, phenolic acids, coumarins, carboxylic acids, amino acids, and vitamins. Essential oil mostly consists of monoterpenoids, particularly D-limonene [18].

Anticancer properties:

An irregular growth of cells or tissues of body is called cancer. A malignant tumor occurs when aberrant cells divide uncontrollably and infect adjacent tissues, commonly known as malignancy. If the abnormal cell growth does not invade nearby tissues is called benign tumor or non-cancerous growth. Plants have many compounds and chemoprotective properties, which are being studied clinically [18]. Inhibiting angiogenesis is a revolutionary cancer therapeutic method. The chosen plants can be employed for anti-angiogenic treatment and cancer control [23]. Citrus limonene contains vitamins C, folate, dietary fiber, and bioactive components including carotenoids and flavonoids that may prevent cancer and degenerative diseases [21].

Anti-ulcer properties:

Peptic ulcers are caused by an imbalance of offensive and suspicious factors, including acid, pepsin, and *H. pylori* (23). Indian medicinal herbs and compounds have been used to treat a variety of ailments, including ulcer conditions. Fruit aqueous extract has antiulcer efficacy on stomach ulcers [13].

Antioxidant properties:

Citrus juices are key sources of antioxidants. Fruits contain antioxidants such as ascorbic acid and flavonoids and substances known as phenolic compounds [11]. The origin of glycosides and Citrus peels consist of phenolic compounds. The active biological molecules Phenolic acids are accountable for the antioxidant properties and numerous additional biological functions are also affected [6]. The antioxidant with the greatest potency Citrus fruits is where activity can be located. Vitamin C (vitamin C) accounts for a large portion in certain fruits can function as an antioxidant. Additionally, there are other plant compounds such as carotenoids, flavonoids, glutathione, and multiple enzymes systems might also play a role in the antioxidant activity [15].

Anti-diabetic properties:

Diabetes is a metabolic illness. Metabolism refers to how our bodies use digested food for energy and development. Food is turned into blood sugar, which is primarily made up of glucose. The primary source of fuel for our bodies is glucose. In the absence of insulin, glucose is unable to enter our cells. Polyphenols are a kind of organic compound found in lemons, particularly in the peel [20]. Polyphenols have been shown to reduce fat formation, blood glucose levels, insulin resistance, hyperlipidaemia, and weight gain, all of which are associated with obesity. Citrus peel contains a diverse spectrum of essential oils. Essential oils effectively destroy or prevent harmful bacteria development. Citrus

peel has large levels of polyphenols, which have been linked to diabetes reduction and anti-oxidative benefits [23].

CONCLUSION

Phytochemicals and nutrients in citrus fruits, particularly lemons, exhibit numerous health benefits and therapeutic properties. Lemons, rich in bioactive compounds such as flavonoids, coumarins, and essential oils, play a significant role in human health. They are excellent sources of vitamin C, which enhances immune function, supports skin health, and facilitates collagen formation. Citrus fruits contribute minimally to daily caloric intake but are dense in essential nutrients like fibre, folate, and antioxidants. Postharvest, lemons are carefully harvested to maintain their quality and maximize nutritional benefits. Beyond nutrition, citrus fruits demonstrate various pharmacological activities, including antioxidant, anti-inflammatory, anticancer, and anti-diabetic properties. Lemon juice has been used in traditional medicine for digestive and skin issues, and modern research supports its efficacy in reducing oxidative stress, improving lipid profiles, and even treating ulcers. The presence of compounds like D-limonene and polyphenols in lemons contributes to their anti-cancer and anti-diabetic properties, while their antioxidant activity, attributed to vitamin C and phenolic compounds, enhances overall health.

REFERENCES

1. Ahmad, M. M., Iqbal, Z., Anjum, F. M., & Sultan, J. I. (2006). Genetic variability to essential oil composition in four citrus fruit species. *Pakistan Journal of Botany*, 38(2), 319.
2. Ali, J., Das, B., & Saikia, T. R. I. D. E. E. P. (2017). Antimicrobial activity of lemon peel (*Citrus limon*) extract. *International Journal of Current Pharmaceutical Research*, 9(4), 79-82.
3. Al-Maskri, A. Y., Hanif, M. A., Al-Maskari, M. Y., Abraham, A. S., Al-sabahi, J. N., & Al-Mantheri, O. (2011). Essential oil from *Ocimum basilicum* (*Omani*

- Basil*): a desert crop. *Natural product communications*, 6(10), 1934578X1100601020.
4. Al-Qudah, T. S., Zahra, U., Rehman, R., Majeed, M. I., Sadique, S., Nisar, S., ... & Tahtamouni, R. W. (2018). Lemon as a source of functional and medicinal ingredient: A review. *Int. J. Chem. Biochem. Sci*, 14, 55-61.
 5. Arias, B. A., & Ramón-Laca, L. (2005). Pharmacological properties of citrus and their ancient and medieval uses in the Mediterranean region. *Journal of Ethnopharmacology*, 97(1), 89-95.
 6. ChunYan, H., Hong, P., ZhenYu, Z., & Jing, S. (2010). Evaluation of antioxidant and antitumour activities of lemon essential oil. *J Med Plant Res*, 4, 1910-5.
 7. Dhanavade, M. J., Jalkute, C. B., Ghosh, J. S., & Sonawane, K. D. (2011). Study antimicrobial activity of lemon (*Citrus lemon* L.) peel extract. *British Journal of pharmacology and Toxicology*, 2(3), 119-122.
 8. Hanif, M. A., Al-Maskri, A. Y., Al-Mahruqi, Z. M. H., Al-Sabahi, J. N., Al-Azkawi, A., & Al-Maskari, M. Y. (2011). Analytical evaluation of three wild growing Omani medicinal plants. *Natural product communications*, 6(10), 1934578X1100601010.
 9. Kamal, G. M., Anwar, F., Hussain, A. I., Sarri, N., & Ashraf, M. Y. (2011). Yield and chemical composition of Citrus essential oils as affected by drying pretreatment of peels. *International Food Research Journal*, 18(4).
 10. Makni, M., Jemai, R., Kriaa, W., Chtourou, Y., & Fetoui, H. (2018). Citrus limon from Tunisia: Phytochemical and physicochemical properties and biological activities. *BioMed research international*, 2018(1), 6251546.
 11. Moosavy, M. H., Hassanzadeh, P., Mohammadzadeh, E., Mahmoudi, R., Khatibi, S. A., & Mardani, K. (2017). Antioxidant and Antimicrobial Activities of Essential Oil of Lemon (*Citrus limon*) Peel in Vitro and in a Food Model. *Journal of Food Quality & Hazards Control*, 4(2).
 12. Mshelia, B. M., Adeshina, G. O., & Onaolapo, J. A. (2018). The antibacterial activity of honey and lemon juice against *Streptococcus pneumoniae* and *Streptococcus pyogenes* isolates from respiratory tract infections. *Acta Sci Microbiol*, 1(3), 22-7.
 13. Nagaraju, B., Anand, S. C., Ahmed, N., Chandra, J. N. S., Ahmed, F., & Padmavathi, G. V. (2012). Antiulcer activity of aqueous extract of *Citrus medica* Linn. fruit against ethanol induced ulcer in rats. *Advances in Biological Research*, 6(1), 24-29.
 14. Nicolosi, E., Deng, Z. N., Gentile, A., La Malfa, S., Continella, G., & Tribulato, E. (2000). Citrus phylogeny and genetic origin of important species as investigated by molecular markers. *Theoretical and Applied Genetics*, 100, 1155-1166.
 15. Oikeh, E. I., Omoregie, E. S., Oviasogie, F. E., & Oriakhi, K. (2016). Phytochemical, antimicrobial, and antioxidant activities of different citrus juice concentrates. *Food science & nutrition*, 4(1), 103-109.
 16. Okwu, D. E. (2008). Citrus fruits: A rich source of phytochemicals and their roles in human health. *Int. J. Chem. Sci*, 6(2), 451-471.
 17. P. Spiegel-Roy, E.E. Goldschmidt. (1996). The biology of citrus. Cambridge University Press: pp.
 18. Rafique, S., Hassan, S. M., Mughal, S. S., Hassan, S. K., Shabbir, N., Pervez, S., ... & Farman, M. (2020). Biological attributes of lemon: A review. *J Addict Med Ther Sci*, 6(1), 030-034.
 19. Shahzadi, I., Nadeem, R., Hanif, M. A., Mumtaz, S., Jilani, M. I., & Nisar, S. (2017). Chemistry and biosynthesis pathways of plant oleoresins: important drug sources. *Int J Chem Biochem Sci*, 12, 18-52.
 20. Sridharan, B., Michael, S. T., Arya, R., Mohana Roopan, S., Ganesh, R. N., & Viswanathan, P. (2016). Beneficial effect of Citrus limon peel aqueous methanol extract on experimentally induced urolithic rats. *Pharmaceutical biology*, 54(5), 759-769.
 21. Tripoli, E., La Guardia, M., Giammanco, S., Di Majo, D., & Giammanco, M. (2007). Citrus flavonoids: Molecular structure, biological activity and nutritional properties: A review. *Food chemistry*, 104(2), 466-479.
 22. Uduak, O. A., Ani, E. J., Etoh, E. C. I., & Macstephen, A. O. (2014). Comparative effect of Citrus sinensis and carbimazole on serum T4, T3 and TSH levels. *Nigerian Medical Journal*, 55(3), 230-234.
 23. Umashanker, M., & Shruti, S. (2011). Traditional Indian herbal medicine used as antipyretic, antiulcer, anti-diabetic and anticancer: A review. *International journal of research in pharmacy and chemistry*, 1(4), 1152-1159.
 24. Vijayalakshmi, K., & Selvaraj, C. (2018). Medicinal Plants and their Phyto-Constituents with Potential Antidiabetic Activity-A Review. *Res. J. Biotech [Internet]*, 92-9.
 25. Zhao, J. (2007). Nutraceuticals, nutritional therapy, phytonutrients, and phytotherapy for improvement of human health: a perspective on plant biotechnology application. *Recent patents on biotechnology*, 1(1), 75-97.



EFFECT OF GIBBERELLIC ACID AND NAPHTHALENE ACETIC ACID ON INITIAL FRUIT SET, DROP, RETENTION, YIELD AND QUALITY OF BER (*ZIZIPHUS MAURITIANA* LAMK.)

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ABSTRACT

The present experiment was conducted in the Horticulture Garden, Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.) from October 2022 to March 2023 to find out the effect of GA₃ and NAA on fruit set, drop, retention, yield and quality of ber cv. Banarasi Karaka. The experiment was carried out using ten treatments viz., T₁-Control, T₂-GA₃ @15 ppm, T₃-GA₃ @ 25 ppm, T₄-GA₃ @ 35 ppm, T₅-NAA @ 10 ppm, T₆-NAA @ 20 ppm, T₇-NAA @ 30 ppm, T₈-GA₃ @ 15 ppm + NAA @ 10 ppm, T₉-GA₃ @ 25 ppm + NAA @ 20 ppm and T₁₀-GA₃ @ 35 ppm + NAA @ 30 ppm, with three replications in Randomized Block Design. The findings of the experiment clearly revealed that the foliar spray of GA₃ @ 35 ppm + NAA @ 30 ppm significantly enhanced initial fruit set (170), fruit retention (19.40%), fruit volume (19.84cc), fruit length (5cm), fruit diameter (3.35cm), fruit weight (15.50g), fruit pulp weight (14.45g), pulp/stone ratio (13.76), TSS (15.30°Brix), ascorbic acid content (99.35 mg/100g pulp), total sugars (10.10%) and yield (32.10 kg/tree). Additionally, this treatment regimen reduced fruit drop (80.10%), stone weight (1.05g) and titratable acidity (0.15%) contents in the plains of North India.

Keywords: Ber, Gibberellic acid and Naphthalene Acetic Acid, Fruit drop, Yield and Quality.

INTRODUCTION

Ber or Indian jujube (*Ziziphus mauritiana* Lamk.) is a subtropical and arid fruit belonging to the family Rhamnaceae, is tetraploid (2n=48) in nature. It is one of the hardy minor fruit crop, which is more suitable for the cultivation in arid conditions of the country as well as in the world. It is popularly known as the 'king of arid fruit'. The fruit is dried and is used as a dessert fruit. It is one of

the most widely cultivated fruit crops, thriving well even in poor soil conditions.

Ber fruit is considered an accessible commodity and is often also referred as the "poor man's fruit". China is the global leader in ber production, followed by India. In India, ber is cultivated across an area of 52,000 hectares, with an annual production of 5,31,000 metric tons (Anonymous, 2022). The fruit contains 14-16% sugars and 150 mg/100 g of vitamin C

as well as other minerals. Various parts of the plant, including the root, bark, leaves, flowers and seeds, have various medicinal uses in Ayurveda and other traditional practices for the treatment of conditions such as diarrhoea, ulcers, indigestion, cough, headache, bleeding gums, and asthma. The ber plant is also utilized as a blood purifier and appetite stimulant (Baloda et al. 2012).

Ripe ber fruits are commonly consumed as fresh and are used to prepare various value-added products such as jam, jelly, preserves and candies. Fresh ber fruits can also be utilized to produce juice, which can subsequently be used to make squash. The fruits develop within the leaf axils of the current year's young growing shoot. Consequently, regular annual pruning is essential to promote vigorous, healthy growth and maximize the fruit-bearing capacity of the tree. Plant growth regulators such as gibberellins and auxins like NAA influences various physiological processes in fruit crops, including ber. Gibberellins and NAA have been found to enhance fruit sets, reduce fruit drop and improve other quality characters.

METHODS AND MATERIALS

The experiment was conducted in the Horticulture Garden, Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.) from October 2022 to March 2023. Kanpur district is located in a subtropical region at an elevation of 135 meters above sea level, with a mean annual rainfall of 108.35 cm. The climate is subtropical, characterized by hot, dry summers and severe cold winters. Healthy, well-established, uniform ber trees of the "Banarasi Karaka" cultivar around 50 years old were selected for the experiment and properly maintained using appropriate horticultural practices and recommended fertilizer applications. The experiment was carried out using ten treatments viz., T₁-Control, T₂-GA₃ @ 15 ppm, T₃-GA₃ @ 25

ppm, T₄-GA₃ @ 35 ppm, T₅-NAA @ 10 ppm, T₆-NAA @ 20 ppm, T₇-NAA @ 30 ppm, T₈-GA₃ @ 15 ppm + NAA @ 10 ppm, T₉-GA₃ @ 25 ppm + NAA @ 20 ppm and T₁₀-GA₃ @ 35 ppm + NAA @ 30 ppm, with three replications in Randomized Block Design.

A foliar spray of plant growth regulators (GA₃ and NAA) was done on 9th November 2023 at the fruit setting stage in the morning hours with a fine nozzle sprayer in each treatment to give uniform spray all over the plant.

Observations were collected from each experimental treatment across all three replications on initial fruit set, fruit drop (%), fruit retention (%), fruit volume (cc), length of fruit (cm), fruit diameter (cm), fruit weight (g), stone weight (g), pulp weight (g), pulp/stone ratio, total soluble solids (°Brix), ascorbic acid (mg/100g), acidity (%), total sugars (%) and fruit yield (kg/tree) using stander and recommended practices. Chemical analysis of fruits was done using the techniques as suggested in AOAC (1980). Data were analyzed according to the method described by Panse and Sukhantme (1984).

RESULTS AND DISCUSSION

Initial fruit set

The initial fruit set per panicle was determined by enumerating the total number of fruits produced on tagged panicles of each treatment and subsequently calculating the average number of fruits per panicle. The initial fruit set was significantly influenced by the foliar application of GA₃, NAA, and their combinations (Table 1). The maximum initial fruit sets (170) were recorded under the plants treated with GA₃ @ 35ppm associated with NAA @ 30ppm (T₁₀) and it was closely followed by initial fruit sets (168) with the treatment of GA₃ 25ppm + NAA 20ppm, whereas the minimum initial fruit sets (148) was counted in control untreated plants. This increased

initial fruit sets during present investigation period might be due to the application of the right concentration of GA₃ which enhanced vegetative growth, leading to increased photosynthesis, thus ultimately increased fruit set (**Chaurasiya et al. 2019**). Additionally, exogenous application of NAA was found to greatly increase the plant's growth, further contributing to the enhanced fruit sets. These findings are in accordance with the reports of **Choudhary et al. (2020)** in ber and **Tripathi and Viveka Nand (2022)** in aonla.

Fruit drop and retention per cent

The foliar application of gibberellic acid and naphthalene acetic acid significantly reduced fruit drop and increased fruit retention compared to the control (Table 1). The combination of GA₃ @ 35 ppm + NAA @ 30 ppm significantly decreased fruit drop (80.10%) and increased fruit retention (19.40%) closely followed by the application of GA₃ @ 25 ppm + NAA @ 20 ppm, which resulted in 82.25% of fruit drop and 17.75% of fruit retention. The control plants experienced the highest fruit drop (94.15%) and the lowest fruit retention (5.85%). When the auxin levels in the fruits decrease, fruit drop occurs due to the formation of an abscission layer, ultimately reducing fruit retention. Exogenous application of GA₃ inhibits ethylene production and higher endogenous gibberellin levels likely counteract the effects of endogenous ABA, which has been linked to fruit drop as reported by **Ebeed et al. 2001**) in mango and **Kumar et al. (2015)** in guava. Similarly, the exogenous application of NAA may have increased the auxin concentration in the plants, potentially leading to a reduction in fruit drop and enhanced fruit retention. These findings are in accordance with the reports of **Lal et al. (2016)** in litchi, **Tripathi and Viveka Nand (2022)** in aonla, **Badal and Tripathi (2021)** in guava.

Fruit volume, length and diameter

The fruit volume, length and diameter were significantly impacted by the foliar application of GA₃, NAA and their combinations (Table 1). Specifically, the combination of GA₃ @ 35 ppm + NAA @ 30 ppm as foliar spray resulted in the highest fruit volume, length and diameter (19.85cc, 5.0cm and 3.35cm, respectively). Similarly, the application of 25 ppm of GA₃ combined application with 20 ppm of NAA (T₉) led to fruit with a volume of 18.30 cc, length of 4.95cm, and diameter of 3.25cm, respectively, whereas the control (untreated) plants produced significantly lower fruit volume, length and diameter (11.45cc, 3.25cm and 2.35cm, respectively). All other tested combinations, along with GA₃ and NAA also produced significantly superior fruits in respect to fruit volume, length and diameter as compared to the control. However, as the plant bio-regulator concentrations were reduced, the fruit volume, length and diameter were also decreased, but the fruits were still considerably larger than those on the untreated plants.

This improvement in fruit volume, length and diameter during present investigation in fruits produced from GA₃ and NAA treated plants may be due to the involvement of GA₃ and NAA to increase the cell division, cell enlargement and translocation of food materials from their production site to the storage organs which might be responsible to an improvement in the fruit volume, length, and diameter the weight. The findings align with the report by **Tripathi et al. (2018)** in aonla, **Tripathi and Shukla (2010)**, **Verma et al., (2021)** in strawberry, and NAA treated plants also promotes cell division, elongation, and intracellular space in monocarpic cells, leading to increased fruit growth rate and size without reducing yield. The results of this study are consistent with previous findings reported by **Sahay et al.**

(2018) in litchi and **Badal and Tripathi (2021)** in guava.

Fruit weight and fruit yield

The weight of fruits (Table 1) and yield (Fig. 1) were recorded at the time of harvesting and it was observed that all treated plants produced significantly more weight of fruits and yield in comparison to control. Significantly maximum fruit weight (15.50g) and yield (32.10 kg/plant) were produced from the plants which were treated with 35ppm of GA₃ in combination with 30ppm of NAA, followed the treatment of GA₃ @ 25ppm + NAA @ 20 ppm (T₉) which exhibited 15.45g fruit weight and 31.18 kg yield/plant. Minimum fruit weight (12.10g) and yield (20.25 kg/plant) were recorded from the plants kept under control (T₁) treatment. It might be because of the reason that the applied plant growth regulators (GA₃ and NAA) led to improved fruit weight and yield due to an increased mobilization of food materials and enhanced cell division and enlargement, resulting in larger fruit size and ultimately increased fruit yield. The findings are align with the report of **Kashyap *et al.* (2023)** in phalsa, **Tripathi and Shukla (2007)** in strawberry, **Radha *et al.* (2023)** in litchi, **Khan *et al.* (2022)** in mango and **Tripathi *et al.* (2018)** in aonla.

Stone weight and pulp weight

The stone weight and pulp weight of fruits were significantly affected by the foliar application of GA₃, NAA along with their combinations (Table 1). Fruit produced from the plants treated with GA₃ @ 35 ppm + NAA @ 30 ppm which substantially reduce stone weight (1.05g) and enhance pulp weight (14.45g), followed by T₉ (25 ppm GA₃ + 20 ppm NAA) weighted 1.08g of stone weight and 14.37g of pulp weight, respectively. In control (untreated) plants, the maximum stone (1.30g) and minimum pulp weight (10.80g) were recorded. It might be due to the reason that the application of GA₃ primarily

promoted cell elongation, increasing overall fruit size by enhancing both stone and pulp growth, with a more pronounced effect on pulp weight. GA₃ also delays fruit maturation, allowing more time for the fruit to accumulate resources in the pulp while having a minimal effect on stone weight. **Tripathi and Shukla (2008)** in strawberry, **Singh *et al.* (2017)** in mango.

Similarly, NAA reduces stone weight by promoting cell division and expanding the pulp tissue more than the stone, resulting in smaller stones. NAA also enhances fruit set, improves pulp weight and leads to larger fruits which are pulpier with a higher flesh-to-stone ratio, making them more marketable. These findings are in line with the reports of **Badal and Tripathi (2021)** in guava and **Tripathi *et al.* (2019)** in mango.

Pulp: stone ratio

The pulp: stone ratio was significantly affected by the foliar application of GA₃, NAA, and their combinations (Table 1). The pulp: stone ratio was calculated by dividing the pulp weight by the stone weight of the fruit. The plants treated with GA₃ @ 35 ppm + NAA @ 30 ppm proved most effective and produced maximum (13.76) pulp: stone ratio, closely followed by treatment of GA₃ @ 25 ppm + NAA @ 20 ppm with a ratio of 13.31. The control treatment had the lowest (8.31) pulp: stone ratio. The combined or sequential application of NAA and GA₃ synergistically stimulate pulp development, enhance fruit retention, and regulate stone size. This culminates in a more advantageous stone: pulp ratio, ultimately improving the overall quality of the fruit. These findings are supported by the reports of **Painkra *et al.* (2012)** in mango and **Kale *et al.* (2000)** in ber.

Total soluble solids

The total soluble solids content of fruit was significantly affected by the foliar application of GA₃, NAA and their combinations (Fig. 2).

The highest total soluble solids contents (15.30 °Brix) were recorded in the fruits which were produced from the plants treated with GA₃ @ 35 ppm + NAA @ 30 ppm (T₁₀), followed by the fruits produced from the plants treated with the treatment of GA₃ @ 25 ppm + NAA @ 20 ppm (T₉), which resulted in the TSS content of 15.25 °Brix. In contrast, the lowest TSS content (12.10 °Brix) was noted under the control treatment. This increase in total soluble solids content of fruits might be due to an increase in amylase activity, which convert stored starch and polysaccharides into simple sugars, leading to an increase in TSS content with the use of NAA. The findings are in accordance with the reports of **Lal *et al.* (2016)** in kinnow, **Kumar *et al.* (2023)** in litchi and **Dodiya *et al.* (2018)** in guava.

Total sugars

The total sugars content was significantly affected by the foliar application of GA₃, NAA, and their combinations (Table 1). The highest of total sugar content (10.10%) was recorded in the fruits which were produced from the plants treated with GA₃ @ 35 ppm + NAA @ 30 ppm (T₁₀), followed by the fruits produced from the treatment of GA₃ @ 25 ppm + NAA @ 20 ppm (T₉), resulting in 9.85% total sugar. In contrast, the lowest total sugar content was noted at 8.30% under the control treatment. It might be due to an increase in total sugars, which was likely due to increased amylase activity converting stored starch and polysaccharides into simple sugars, leading to improved total sugar levels with the use of NAA. The findings follow the reports of **Lal *et al.* (2016)** in kinnow, **Kumar *et al.* (2023)** in litchi and **Dodiya *et al.* (2018)** in guava.

Ascorbic acid

During present investigation all the

treatments significantly increased ascorbic acid content over the control (Table 1). The maximum ascorbic acid content of 99.35 mg/100g was recorded under the treatment of GA₃ @ 35 ppm + NAA @ 30 ppm (T₁₀), closely followed by T₉ (GA₃ @ 25 ppm + NAA @ 20 ppm) and T₈-GA₃ @ 15 ppm + NAA @ 10 ppm, which had an ascorbic acid content of 98.45 and 97.85 mg/100g, respectively. The minimum ascorbic acid content of 80.10 mg/100g was recorded under the control. The rise in ascorbic acid levels may have stemmed from increased ascorbic acid synthesis facilitated by favourable metabolic processes involving specific enzymes and metabolic ions, potentially influenced by GA₃. These findings align with the reports of **Dhillan and Singh (1968)** and **Masalkar and Wavhal (1991)** in ber.

Titrateable acidity

The acidity of ber fruits was significantly reduced by applying GA₃ and NAA (Table 1). The minimum acidity (0.15%) was recorded with treatment GA₃ @ 35 ppm + NAA @ 30 ppm (T₁₀) followed by a treatment of T₉ (GA₃ 25ppm + NAA 20ppm) exhibited 0.25% of titrateable acidity and all other treatments also results in reduced acidity in fruit except control, which produced maximum titrateable acidity content (0.95%). This decrease in acidity with the application of NAA could be explained that organic acid might be utilized rapidly in respiration. The application of GA₃ may be attributed to the quick metabolic transformation of starch and pectin into acidity compounds and the rapid translocation of sugars from fruit to leaves of developing fruits. The present findings are in conformity to the result of **Kumar *et al.* (2023)** in phalsa and **Kumar *et al.* (2022)** in ber.

Table 1. Effect of foliar feeding of GA₃ and NAA on physical quality parameters of ber cv. Banarasi Karaka.

Treatments	Initial fruit set	Fruit drop (%)	Fruit retention (%)	Fruit volume (cc)	Length of fruit (cm)	Fruit diameter (cm)	Fruit weight (g)	Stone weight (g)
T ₁ -Control	148	94.15	5.85	11.45	3.25	2.35	12.10	1.30
T ₂ -GA ₃ 15 ppm	155	90.25	9.75	12.25	4.25	2.65	14.85	1.25
T ₃ -GA ₃ 25 ppm	157	88.75	11.25	13.45	4.35	2.75	14.95	1.23
T ₄ -GA ₃ 35 ppm	160	85.45	14.55	14.25	4.45	2.85	15.15	1.20
T ₅ -NAA 10 ppm	153	91.25	8.75	12.10	3.60	2.60	14.45	1.18
T ₆ -NAA 20 ppm	155	89.35	10.65	11.85	3.45	2.52	14.65	1.15
T ₇ -NAA 30 ppm	156	87.25	12.75	11.45	3.30	2.48	14.75	1.13
T ₈ -GA ₃ 15 ppm + NAA 10 ppm	165	83.45	16.55	16.25	4.85	3.10	15.30	1.10
T ₉ -GA ₃ 25ppm + NAA 20 ppm	168	82.25	17.75	18.30	4.95	3.25	15.45	1.08
T ₁₀ - GA ₃ 35 ppm + NAA 30 ppm	170	80.10	19.40	19.85	5.00	3.35	15.50	1.05
S.E.(d)±	3.12	1.93	0.32	0.30	0.09	0.07	0.23	0.02
C.D. at 5%	6.62	4.08	0.68	0.65	0.19	0.16	0.50	0.05

Table 1. Effect of foliar feeding of GA₃ and NAA on pulp weight and chemical quality parameters of ber cv Banarasi Karaka.

Treatments	Pulp weight (g)	Pulp/stone ratio	Total sugars (%)	Ascorbic acid (mg/100g)	Titratable acidity (%)
T ₁ -Control	10.80	8.31	8.30	80.10	0.95
T ₂ -GA ₃ 15 ppm	13.60	10.88	8.96	92.90	0.70
T ₃ -GA ₃ 25 ppm	13.72	11.15	9.00	95.15	0.45
T ₄ -GA ₃ 35 ppm	13.95	11.63	9.15	95.30	0.38
T ₅ -NAA 10 ppm	13.27	11.24	8.75	90.45	0.92
T ₆ -NAA 20 ppm	13.50	11.74	8.45	91.15	0.88
T ₇ -NAA 30 ppm	13.62	12.05	8.25	92.25	0.85
T ₈ -GA ₃ 15 ppm + NAA 10 ppm	14.20	12.91	9.45	97.85	0.35
T ₉ -GA ₃ 25ppm + NAA 20 ppm	14.37	13.31	9.85	98.45	0.25
T ₁₀ -GA ₃ 35 ppm + NAA 30 ppm	14.45	13.76	10.10	99.35	0.15
S.E.(d)±	0.27	0.26	0.22	1.87	0.01
C.D. at 5%	0.58	0.56	0.47	3.97	0.02

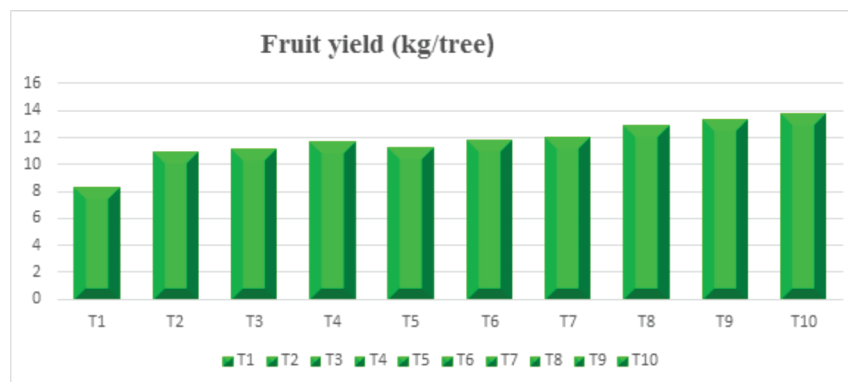
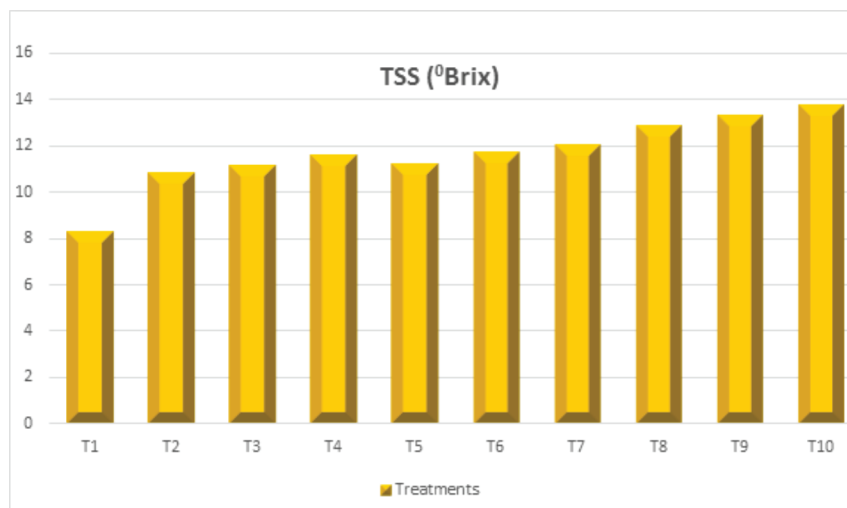


Fig. 1. Influence of foliar application of GA₃ and NAA on fruit yield (kg/tree)Fig. 2. Influence of foliar application of GA₃ and NAA on the total soluble solid content of fruit (°Brix)

CONCLUSION

The findings of the experiments clearly shows that the foliar spray containing GA₃ @ 35 ppm + NAA @ 30 ppm substantially enhanced various parameters like increased initial fruit set, fruit retention, fruit volume, fruit length, fruit diameter, fruit weight, pulp weight, pulp/stone ratio, total soluble solids, ascorbic acid, total sugars and fruit yield (kg/plant). Additionally, this treatment regimen reduced fruit drop, stone weight and titratable acidity contents. Based on the present experimental findings, it is recommended that GA₃ @ 35 ppm + NAA @ 30 ppm should be used to improve the flowering, fruiting, yield, and overall quality of ber growers in the plains of North India.

REFERENCES

1. **Anonymous (2022)** nhb.gov.in/horticulturedatabase/ National Horticulture Board, Gurugram Haryana.
2. **AOAC (1980).** *Official Methods of Analysis*. Association of Official Analytical Chemists, Washington DC.
3. **Badal, D. S. and Tripathi, V. K. (2021).** Influence of foliar feeding of NAA and Boron on growth, flowering, fruiting, and yield of winter season guava (*Psidium guajava* L.) cv. L-49. *Biological Forum-An International Journal*, **13**(3): 387-391.
4. **Baloda, S., Sehrawat, S.K., Yadav, B.S., Ahlawat, V.P. and Singh, S. (2012).** Present status of ber production and future thrusts in India: A review. *Agricultural Reviews*, **33**(3), 256–264.
5. **Chaurasiya, G. R., Sharma, A., Tiwari, S., Goyal, G., Bhadauria, A. S., Singh, A.P. and Yadav, A. (2019).** Influence of foliar application of GA₃ with and without NAA on fruit drop, growth, yield and quality of ber (*Zizyphus mauritiana* Lamk.). *International Journal of Current Microbiology and Applied Sciences*, **8**: 45-56.
6. **Choudhary, R.B., Bairwa, L.N., Garhwal, O.P. and Negi, P. (2020).** Effect of plant growth regulators and nutrients on yield attributing characters and yield of ber (*Zizyphus mauritiana* Lamk.) *Journal of Pharmacognosy and Phytochemistry*, **9**(4): 1968-197.
7. **Dhillon, H.S. and Singh, K. (1968).** Effect of some plant regulators on fruit set and fruit drop in ber (*Zizyphus jujuba* L.). *Journal of Research PAU*, **5**:392-394.
8. **Dodiya, K.D., Dalvadi, A.C., Halepotara, F.H. and Solanki, S.P. (2018).** Effect of foliar application of plant growth regulators and boron on quality of guava (*Psidium guajava* L.) cv. L-49. *International Journal of Chemical Studies*, **6**(3): 1396-1398.
9. **Ebeed, S., El-Gazzar, A. and Bedier, R. (2001).** Effect of foliar application of some micronutrients and growth regulators on fruit drop, yield, fruit quality and leaf mineral content of mango cv. Mesk. *Annals of Agricultural Science*, **39**: 1279-1296.
10. **Kale, V.S., Dod, V.N., Adpawar, R.N. and Bharad, S.G. (2000).** Effect of PGR on fruit characters and quality of ber. *Crop Research*, **20**(2): 327–333.
11. **Kashyap, S., Tripathi, V. K. and Kumar, V. (2023).** Effect of gibberellic acid and boron alone and its combination on vegetative growth, fruiting, and yield of phalsa. *Annals of Horticulture*, **16**(2): 123–129.

12. Khan, A.U., Tripathi, V. K., Gautam, R.K.S. and Dwivedi, A.K. (2022). Effect of GA₃ NAA and zinc sulphate of mango (*Mangifera indica* L.) cv. Dashehari. *Biological Forum-An International Journal*, 14(4): 320–325.
13. Kumar, Dharmendra, Dwivedi, A. K., Tripathi, V. K. and Pandey, Shiwananad (2023). Influence of different levels of NAA and zinc sulphate on fruiting, yield and quality attributes of litchi cv. Dehradun. *Prog. Agric.* 23 (1): 150-158. DOI: 10.5958/0976-4615.2023.00021.2
14. Kumar, Dinesh, Dwivedi, A. K., Tripathi, V. K. and Pandey, Shiwananad (2023). Effect of NAA and GA₃ on growth, yield and quality attributes of phalsa (*Grewia subinaequalis* D.) C. cv. Sharbati. *Prog. Agric.* 23 (1): 159-165. DOI: 10.5958/0976-4615.2023.00023.6
15. Kumar, J., Kumar, R., Rai, R. and Mishra, D. S. (2015). Effect of nutrients and plant growth regulators on physico-chemical parameters and yield of guava (*Psidium guajava* L.) cv. Pant Prabhat. *The Bioscan*, 10(2): 495-498.
16. Kumar, T., Kumar, D., Gangwar, V., Singh, N., Gautam, R. K., and Chauhan, N.K. and Patel, S.K. (2022). Effect of Foliar Application of GA₃, NAA and Urea on Fruit Quality Attributes of Ber (*Zizyphus mauritiana* Lamk.) cv. Banarasi Karaka. *Biological Forum – An International Journal*, 14(3): 635-638.
17. Lal, D., Tripathi, V. K., Nayyer, M. A., Kumar, S., Ahmed, M. and Siddiqui, M. W. (2016). Pre-harvest spray of Gibberellic Acid, NAA, and Calcium Nitrate on fruit retention, yield and quality of Kinnow Mandarin. *Environment and Ecology*, 34 (4C): 2288-2292.
18. Masalkar, S.D. and Wavhal, K.N. (1991). Effect of various growth regulators on physico-chemical properties of ber cv. Umran. *Maharashtra J Hort*, 5(2): 37-40.
19. Painkra, R.K., Panigrahi, H.K. and Prabhakar, S. (2012). Effect of plant growth regulators on fruit drop and physicochemical composition of mango (*Mangifera indica* L.) cv. Langra. *Flora and Fauna*, 18(2): 213–216.
20. Panse V.G. and Sukhatme, P.V. (1984) Statistical methods for agricultural workers. Third Edition, Indian Council of Agricultural Research, New Delhi.
21. Radha., Tripathi, V. K., Verma, S. and Mishra, A. (2023). Influence of different levels of boron and NAA on fruiting yield and quality attributes of litchi (*Litchi chinensis* Sonn.). *Annala of Horticulture*, 16(2): 130–140.
22. Sahay, S., Kumari, P., Mishra, P.K., Rashmi, K., Shrivastava, P., Ahmad, M.F. and Kumar, R. (2018). Pre harvest foliar spray of micronutrient and growth regulators on yield attributes of litchi (*Litchi chinensis* Sonn.) “Purbi”. *Acta Horticulture*, 12(11):19.
23. Singh, Tilak, Tripathi, V. K. and Tiwari, Prakash (2017). Influence of pre-harvest application of plant bio-regulators and micronutrients on fruit retention, yield and quality attributes of mango. *Progressive Research-An International Journal*, 12 (Special-IV): 2640-2644.
24. Tripathi, V. K. and Shukla, P.K. (2007). Influence of plant bio-regulators, boric acid and zinc sulphate on yield and fruit characters of strawberry cv. Chandler. *Progressive Horticulture*, 39 (2): 154-158.
25. Tripathi, V. K. and Shukla, P.K. (2010). Influence of plant bio-regulators, boric acid and zinc sulphate on yield and fruit characters of strawberry cv. Chandler. *Progressive Horticulture*, 42 (2):186-188.
26. Tripathi, V. K. and Shukla, P.K. (2008). Influence of plant bio-regulators and micronutrients on flowering and yield of strawberry cv. Chandler. *Annals of Horticulture*, 1(1) :45-48.
27. Tripathi, V. K. and Viveka Nand (2022). Effect of foliar application of Boron, Zinc and NAA on fruit retention, yield and quality attributes of aonla. *Progressive Horticulture*, 54(1): 76-81.
28. Tripathi, V. K., Pandey, S.S., Kumar, A., Dubey, V. and Tiwari, P. (2018). Influence of foliar application of gibberellic acid, calcium, and boron on fruit drop, yield, and quality attributes of aonla (*Emblca officinalis*) cv. NA-7. *Indian Journal of Agricultural Sciences*, 88(11): 1784–1788.
29. Tripathi, V. K., Singh, A., Bhadauria, A.S. and Gupta, S. (2019). Influence of GA₃ and naphthalene acetic acid alone and in combination on fruit drop, yield, and quality of mango cv. amrapali. *Progressive Research-An International Journal*, 14(1): 10–13.
30. Verma, Somendra, Dwivedi, A.K. and Tripathi, V. K. (2021). Effect of gibberellic acid and boron on growth, yield and yield attributory traits in strawberry (*Fragaria x ananassa* Duch.) under North Gangetic Plains. *Biological Forum-An International Journal* 13(3): 262-267.



IMPACT OF INTEGRATED NUTRIENT MANAGEMENT ON BIOCHEMICAL PARAMETERS OF ONION (*ALLIUM CEPA* L.) CV. PUSA RED.

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ABSTRACT

A field experiment was carried out to study the impact of integrated nutrient management on biochemical parameters of onion (*Allium cepa* L) cv. Pusa Red. The field experiment was conducted at Horticultural Research Farm, Department of Horticulture, Chaudhary Charan Singh University, Meerut (U.P.) India, during the years 2019-20 and 2020-21. The experiment was laid out in randomized block design with fourteen treatments and three replications. Based on the experimental study, it is clearly indicated that application of 75% RDF + Vermicompost @ 12.5 q/ha + Azospirillum @ 5 kg/ha gave the better effect on biochemical character (total soluble solids, nitrogen content in bulb, phosphorus content in bulb and potassium content in bulb). The maximum total soluble solids (12.82 °B), nitrogen content in bulb (1.86 %), phosphorus content in bulb (0.91 %) and potassium content in bulb (2.84 %) were recorded with the application of 75% RDF + Vermicompost @ 12.5 q/ha + Azospirillum @ 5 kg/ha. However, maximum chlorophyll in leaf (0.115 mg/m²), chlorophyll 'a' in leaf (0.076 mg/m²) and chlorophyll 'b' in leaf (0.038 mg/m²) were recorded under 50% RDF + Vermicompost @ 25 q/ha + Azotobacter @ 5 kg/ha.

Keywords: INM, Onion, Biofertilizers, Biochemicals

INTRODUCTION

Onion (*Allium cepa* L.), 2n = 16, belongs to the family *Alliaceae*, genus *Allium*, and it is one of the important bulb crops. The onion is one of our oldest vegetables and it has been grown in India since very ancient times, as it is mentioned in Charak-samhita. In India, onion is cultivated over 1624 thousand hectares of area with 26641 thousand metric tonnes of production in 2020-21 (National Horticulture Board). In India, onion is mainly grown in ten states, namely Maharashtra, Gujarat,

Rajasthan, Uttar Pradesh, Orissa, Karnataka, Tamil Nadu, Haryana, Bihar and Andhra Pradesh. These ten states together produced 95 percent of onion. Maharashtra has first rank in area and production of onion. In Uttar Pradesh, onion is grown over a 30 thousand-hectare area with an annual production of 509.80 thousand metric tonnes.

The onion is consumed by almost everybody either as raw in salad form or as cooked along with spices and vegetables. Primarily the bulb is used as a vegetable, but in some places the green onions are also

cooked. Sometimes the flowering shoots known as 'scape' is also used as vegetables. There are several local preparations of onion in different parts of the country. Onions are highly valued vegetables and stored as pickles. It is rich in minerals like phosphorus and calcium and carbohydrates. 100 g of edible portion of onion bulb contains 86.6% moisture, 11.1 g carbohydrate, 1.2 g protein, 0.1 g fat, 0.08 mg thiamine, 0.01 mg riboflavin, 11 mg vitamin, 47 mg calcium and 0.07 mg iron (Dhaliwal, 2008). Onions are a vital rejuvenator and revitalizes (Rai and Yadav, 2005).

The current agriculture system depends on chemical fertilizers which are harmful for soil health and ecology. Due to the chemical fertilizers, the soil health is decreasing day by day because such nutrients rapidly convert into unavailable forms. Therefore, integrated nutrient management (INM) may be a useful solution to handle this kind of problem for a sustainable production system. Integrated nutrient management is a way to use chemical fertilizers and organic manures in a judicious combination for sustainable agriculture production. INM practice is important to supply all essential nutrient elements required by the plants for optimum growth and development. Chemical fertilizers which are artificially synthesized and have a high concentration of nutrient elements, are rapidly released in soil and easily uptake by the plant roots. The uptake of nutrients by plants involves several biochemical and physiological processes occurring both within and outside the plant roots (Mengel and Kirkby, 2001). Organic manures such as FYM and vermicompost are eco-friendly, low-cost agricultural inputs playing a significant role in improving nutrient availability.

A complex green pigment called chlorophyll, which is present in plants, algae, and some bacteria, is essential to photosynthesis because it absorbs light energy

and transforms it into chemical energy (Bjorn *et al.* 2009). Levels of chlorophyll in the leaves of onions play a vital role in the production of bulbs. A high level of chlorophyll in leaves helps to produce sugars that are used for growth and storing reserves in bulbs. Since higher TSS levels typically correlate with better keeping quality and higher sugar content within the bulb, TSS (Total Soluble Solids) is an important metric to consider when assessing various onion varieties, growing conditions, or storage techniques. TSS is a critical indicator of the quality of the onion, especially with regard to its storability and suitability for processing. (Netrapal *et al.*, 1988; Dhotre *et al.*, 2010) indicated that high TSS is positively correlated with the storability of onion bulbs.

Nitrogen, phosphorus and potassium levels in onion bulbs are also essential to human health, as reported by many scientists. Nitrogen is a crucial part of the human body. Nitrogen is a necessary nutrient for the synthesis of proteins, amino acids, nucleic acids, and other substances. Phosphorus is an important component of both skeletal and non-skeletal tissues; phosphorus is crucial for the synthesis of energy. The potassium facilitates the proper movement of waste products and nutrients throughout the body's cells as well as the health of the heart, muscles, and nerves.

MATERIALS AND METHODS

The experiment was conducted to study the impact of integrated nutrient management on biochemical parameters of onion (*Allium cepa* L.) cv. Pusa Red during Rabi season at Horticultural Research Farm, Department of Horticulture, Chaudhary Charan Singh University Campus, Meerut (U.P.) India, during the years 2019-20 and 2020-21. The treatments involved in the study were fourteen in numbers i.e. T₁ (control), T₂ (Recommended dose of NPK/ha (100:80:50 kg),

T₃ (75% RDF + FYM @ 5 t/ha), T₄ (75% RDF + FYM @ 5 t/ha + Azotobacter @ 5 kg/ha), T₅ (75% RDF + FYM @ 5 t/ha + Azospirillum @ 5 kg/ha), T₆ (75% RDF + Vermicompost @ 12.5 q/ha), T₇ (75% RDF + Vermicompost @ 12.5 q/ha + Azotobacter @ 5 kg/ha), T₈ (75% RDF + Vermicompost @ 12.5 q/ha + Azospirillum @ 5 kg/ha), T₉ (50% RDF + FYM @ 10 t/ha), T₁₀ (50% RDF + FYM @ 10 t/ha + Azotobacter @ 5 kg/ha), T₁₁ (50% RDF + FYM @ 10 t/ha + Azospirillum @ 5 kg/ha), T₁₂ (50% RDF + Vermicompost @ 25 q/ha), T₁₃ (50% RDF + Vermicompost @ 25 q/ha + Azotobacter @ 5 kg/ha) and T₁₄ (50% RDF + Vermicompost @ 25 q/ha + Azospirillum @ 5 kg/ha). The experiment was laid out in randomized block design (RBD) and replicated three times. The soil of the experimental field was well drained, sandy loam having good moisture and heat-absorbing capacity. As per treatments, well-rotten farm yard manure (FYM) and vermicompost were incorporated in the soil seven days before transplant of seedlings. Similarly, biofertilizers were also applied seven days before transplanting of seedlings as per treatment. In the case of inorganic fertilizers (NPK), half doses of nitrogen and a full dose of phosphorus and potash were applied as a basal dressing at the time of transplanting. The remaining half dose of nitrogen was applied 45 days after transplanting of seedlings. Forty-day-old, healthy, vigor-stocky, and uniform seedlings of onion were transplanted in the experimental field. All biochemical parameters were analysis in the laboratory of the Department of Horticulture and Department of Botany, Ch. Charan Singh University Campus, Meerut (U.P.). Total soluble solids (TSS) of onion bulb juice were determined with the help of a hand refractometer. Estimation of nitrogen was done with wet digestion of samples with H₂SO₄ and H₂O₂ by Colorimetric method using Spectronic-20 after development of colour with Nessler's reagent (Snell and

Snell, 1939). Phosphorus is estimated by the Vanadomolybdo phosphate yellow colour method (Jackson, 1967) and potassium is estimated by the flame photometric method (Jackson, 1967). The chlorophyll content in the leaf was determined by the dimethyl sulfoxide method (DMSO) of Hiscox and Israelstam (1979).

RESULT AND DISCUSSION

The data related to biochemical parameters exhibited in table-1 and table-2 which shows that the application of integrated nutrient management gave a major impact on chlorophyll in leaf, chlorophyll 'a' in leaf, chlorophyll 'b' in leaf, TSS, nitrogen content in bulb, phosphorus content in bulb and potassium content in bulb during both the years of investigation. Chlorophyll is an important biochemical trait that determines the photosynthetic activity of plants and essential for enhance economic yield. Other biochemical parameters, namely, TSS and N, P & K content in bulbs are important for nutritive quality of food (Abdin *et al.* 1993). The maximum content of total chlorophyll (0.115 mg/g), chlorophyll 'a' (0.076 mg/g) and chlorophyll 'b' (0.038 mg/g) were recorded with the soil application of 50% RDF + Vermicompost @ 25 q/ha + Azotobacter @ 5 kg/ha followed by 75% RDF + Vermicompost @ 12.5 q/ha + Azotobacter @ 5 kg/ha (0.111 mg/g, 0.074 mg/g and 0.036 mg/g) during both years of investigation. While minimum chlorophyll (0.069 mg/g), chlorophyll 'a' (0.046 mg/g) and chlorophyll 'b' content in leaf (0.023 mg/g) were recorded under control. Similar result was reported by Verma *et al.* (2013). High level of chlorophyll in leaves of onion might be due to the high nutrient level especially nitrogen and magnesium of the plant. Since vermicompost and FYM organic manure supply a good amount of nitrogen & magnesium, so these organic manures help in increasing chlorophyll content of leaves. Many

researchers reported that nitrogen and magnesium levels of plants directly affect the chlorophyll content of plant leaves. Hokmalipour and Dorbandi, (2011) reported that nitrogen is an important structural component and is required for the enzymes involved in chlorophyll synthesis. Similarly, magnesium is a structural component of chlorophyll and activates more than 300 enzymes as reported by Beale, (1999).

Total soluble solids content in the bulb is an important quality parameter. The data reported that there was no significant effect found on TSS (°B) under the INM treatment. However, the maximum total soluble solids based on pool data, (12.82 °B) was observed with 75% RDF + Vermicompost @ 12.5 q/ha + Azospirillum @ 5 kg/ha. While minimum total soluble solids content (11.46 °B) was recorded in control during the investigation years 2019-20 and 2020-21. The possible reason depicted for the increase in TSS content with the application of inorganic and organic fertilizers in combination with biofertilizers, over recommended doses of NPK and control may be due to more utilization of inorganic nitrogen in the presence of biofertilizers, better development of the root system and possibly higher synthesis of plant growth hormones. So, it may have helped in increasing the sugar content in the bulb. Related results were found by Yadav *et al.* (2015), Prakash *et al.* (2000), Singh *et al.* (2002), Jayathilake *et al.*, (2003) and Indira and Singh (2014).

The nitrogen content in bulbs was affected significantly by integrated nutrient management during both years of experiments. Maximum nitrogen content in onion bulbs was obtained with the application of 75% RDF + Vermicompost @ 12.5 q/ha + Azospirillum @ 5 kg/ha (1.86%) which was found statistically at par with 50% RDF + Vermicompost @ 25 q/ha + Azospirillum @ 5 kg/ha (1.85%). The minimum nitrogen content

in onion bulbs was found in control (0.99%). The increase nitrogen content in bulb were also observed by Singh *et al.* (1996), Yadav (2000), Sharma *et al.* (2003) and Radwan and Hussein (2000). The higher nitrogen content in bulbs might be due to the significant built up of the colonies of nitrogen-fixing bacteria specially azospirillum and azotobacter with the application of organic manure. So, this reason is inevitable because plants take more nitrogen from the soil. The decomposition and mineralization of manures ensures a better supply of available nitrogen directly to the plants and has a solubilizing effect on fixed form of mineral nutrients. It also provides a better soil environment, which may be the reason for the higher content of nitrogen in onion bulbs as a result of applying vermicompost with azotobacter (Sreenivas *et al.* 2000).

It is apparent from the data presented in table-2 that different levels of fertility, organic manure, and chemical fertilizers significantly influenced the phosphorus content in onion bulbs during both years of investigation. The maximum phosphorus content in onion bulb was obtained with the application of 75% RDF + Vermicompost @ 12.5 q/ha + Azospirillum @ 5 kg/ha (0.91%) followed by 50% RDF + Vermicompost @ 25 q/ha + Azospirillum @ 5 kg/ha (0.85%). The minimum phosphorus content in onion bulbs was found in control (0.31%). Similar findings have been earlier reported by Sharma *et al.* (2003), Radwan and Hussein (2000). The increase in phosphorus content in bulbs due to these treatments could possibly be due to increased availability of phosphorus in soil by the application of organic manures which not only supply phosphorus but also make favorable soil conditions for better colonization of beneficial microorganisms like nitrogen fixing bacteria, phosphorus solubilizing bacteria etc. Havlin *et al.* (1999) reported that organic compounds in soil increased the phosphorus availability

through the formation of organic phosphate complexes that are more easily assimilated by plants and increased the quantity of organic phosphorus which mineralized into inorganic phosphorus.

A critical examination of the data presented in tables-2 revealed a significant effect of soil application of organic and inorganic fertilizers on potassium content in bulbs. The maximum potassium content in onion bulb was obtained with the application of 75% RDF + Vermicompost @ 12.5 q/ha + Azospirillum @ 5 kg/ha (2.84%) followed by 50% RDF + Vermicompost @ 25 q/ha + Azospirillum @ 5 kg/ha (2.79%). The minimum potassium content in onion bulbs was found in control (1.40%). The results are in agreement with the findings reported by Singh and Pandey (2006) & Radwan and Hussein (2000). The notable increase in potassium uptake suggests that integrating nutrient supply

sources is necessary for onion crops, as well as for general improvements to the physico-chemical characteristics of the soil and its biological environment (Sharma *et al.* 2003 and Sharma *et al.* 2009).

CONCLUSION

Inorganic, organic and biofertilizers applied to the soil had a positive effect on the biochemical parameters of onion, as demonstrated by the current experimental study. According to the current research it may be concluded that soil application of 75% RDF + Vermicompost @ 12.5 q/ha + Azospirillum @ 5 kg/ha increase the levels of nitrogen, phosphorus and potassium content in onion bulbs, as well as TSS. Similarly, soil application of 50% RDF + Vermicompost @ 25 q/ha + Azotobacter @ 5 kg/ha may be proven more beneficial to enhance the level of chlorophyll in onion leaves.

Table 1:- Effect of Integrated nutrient management on chlorophyll, chlorophyll 'a' and chlorophyll 'b' content in leaf of onion (*Allium cepa* L.) cv. Pusa Red.

Not.	Treatment	chlorophyll in leaf (mg/m ²)		Pool data	chlorophyll in leaf 'a' (mg/m ²)		Pool data	chlorophyll in leaf 'b' (mg/m ²)		Pool data
		2019-20	2020-21		2019-20	2020-21		2019-20	2020-21	
T ₁	Control	0.073	0.066	0.069	0.048	0.044	0.046	0.024	0.022	0.023
T ₂	Recommended dose of NPK/ha (100:80:50 kg)	0.079	0.088	0.083	0.053	0.059	0.056	0.026	0.029	0.027
T ₃	75% RDF + FYM @ 5 t/ha	0.086	0.089	0.087	0.057	0.060	0.058.5	0.028	0.03	0.029
T ₄	75% RDF + FYM @ 5 t/ha + Azotobacter @ 5 kg/ha	0.097	0.100	0.098	0.066	0.067	0.066.5	0.033	0.033	0.033
T ₅	75% RDF + FYM @ 5 t/ha + Azospirillum @ 5 kg/ha	0.093	0.099	0.096	0.065	0.066	0.065.5	0.032	0.03	0.031
T ₆	75% RDF + Vermicompost @ 12.5 q/ha	0.101	0.102	0.101	0.068	0.068	0.068	0.034	0.034	0.034
T ₇	75% RDF + Vermicompost @ 12.5 q/ha + Azotobacter @ 5 kg/ha	0.106	0.117	0.111	0.071	0.078	0.074.5	0.035	0.039	0.037
T ₈	75% RDF + Vermicompost @ 12.5 q/ha + Azospirillum @ 5 kg/ha	0.103	0.105	0.104	0.069	0.070	0.069.5	0.034	0.035	0.034
T ₉	50% RDF + FYM @ 10 t/ha	0.093	0.092	0.092	0.062	0.061	0.061.5	0.031	0.03	0.030
T ₁₀	50% RDF + FYM @ 10 t/ha + Azotobacter @ 5 kg/ha	0.103	0.102	0.102	0.069	0.068	0.068.5	0.034	0.034	0.034
T ₁₁	50% RDF + FYM @ 10 t/ha + Azospirillum @ 5 kg/ha	0.098	0.101	0.099	0.066	0.068	0.067	0.033	0.034	0.033

T ₁₂	50% RDF + Vermicompost @ 25 q/ha	0.106	0.112	0.109	0.071	0.075	0.073	0.035	0.037	0.036
T ₁₃	50% RDF + Vermicompost @ 25 q/ha + Azotobacter @ 5 kg/ha	0.110	0.120	0.115	0.073	0.080	0.076.5	0.036	0.040	0.038
T ₁₄	50% RDF + Vermicompost @ 25 q/ha + Azospirillum @ 5 kg/ha	0.104	0.109	0.106	0.070	0.073	0.071.5	0.035	0.036	0.035
	CD at 5%	0.010	0.018		0.003	0.011		0.003	0.006	
	SE +	0.003	0.006		0.001	0.004		0.001	0.002	

Table 2:- Effect of Integrated nutrient management on nitrogen, phosphorus and potassium content in bulb of onion (*Allium cepa* L.) cv. Pusa Red.

Not.	Treatment	Nitrogen in bulb (%)		Pool data	Phosphorus in bulb (%)		Pool data	Potassium in bulb (%)		Pool data
		2019-20	2020-21		2019-20	2020-21		2019-20	2020-21	
T ₁	Control	1.11	0.88	0.99	0.43	0.20	0.31	1.89	1.03	1.46
T ₂	Recommended dose of NPK/ha (100:80:50 kg)	1.30	1.37	1.33	0.47	0.55	0.51	2.05	2.10	2.07
T ₃	75% RDF + FYM @ 5 t/ha	1.31	1.40	1.35	0.48	0.56	0.52	2.05	2.16	2.10
T ₄	75% RDF + FYM @ 5 t/ha + Azotobacter @ 5 kg/ha	1.70	1.75	1.72	0.72	0.79	0.75	2.15	2.29	2.22
T ₅	75% RDF + FYM @ 5 t/ha + Azospirillum @ 5 kg/ha	1.75	1.78	1.76	0.76	0.82	0.79	2.28	2.34	2.31
T ₆	75% RDF + Vermicompost @ 12.5 q/ha	1.48	1.47	1.47	0.58	0.67	0.62	2.12	2.24	2.18
T ₇	75% RDF + Vermicompost @ 12.5 q/ha + Azotobacter @ 5 kg/ha	1.79	1.81	1.80	0.80	0.82	0.82	2.28	2.37	2.32
T ₈	75% RDF + Vermicompost @ 12.5 q/ha + Azospirillum @ 5 kg/ha	1.85	1.87	1.86	0.90	0.92	0.91	2.79	2.90	2.84
T ₉	50% RDF + FYM @ 10 t/ha	1.42	1.44	1.43	0.51	0.57	0.54	2.08	2.18	2.13
T ₁₀	50% RDF + FYM @ 10 t/ha + Azotobacter @ 5 kg/ha	1.52	1.55	1.53	0.64	0.74	0.69	2.13	2.24	2.18
T ₁₁	50% RDF + FYM @ 10 t/ha + Azospirillum @ 5 kg/ha	1.66	1.67	1.65	0.69	0.77	0.73	2.15	2.28	2.21
T ₁₂	50% RDF + Vermicompost @ 25 q/ha	1.43	1.46	1.44	0.54	0.60	0.57	2.08	2.20	2.14
T ₁₃	50% RDF + Vermicompost @ 25 q/ha + Azotobacter @ 5 kg/ha	1.79	1.84	1.81	0.82	0.84	0.83	2.31	2.43	2.37
T ₁₄	50% RDF + Vermicompost @ 25 q/ha + Azospirillum @ 5 kg/ha	1.84	1.87	1.85	0.84	0.86	0.85	2.75	2.84	2.79
	CD at 5%	0.186	0.046		0.04	0.04		0.023	0.027	
	SE +	0.080	0.016		0.01	0.01		0.008	0.009	

REFERENCES

1. **Abdin, M. Z., & Abrol, Y. P. (1993).** Effect of split N-application on growth and yield of wheat (*T.aestivum* L.) Genotypes. In *Plant Nutrition—from Genetic Engineering to Field Practice: Proceedings of the Twelfth International Plant Nutrition Colloquium*, 21–26 September 1993, Perth, Western Australia (pp. 529-532). Springer Netherlands.
2. **Association of Official Analytical Chemists (AOAC, 1970).** Official Methods of Analysis,” 10th Edition, Washington D.C., pp. 154-170.
3. **Beale, S. I. (1999).** Enzymes of chlorophyll biosynthesis. *Photosynthesis research*, 60, 43-73.

4. Bjron, L. O., Papageorgiou, G. C., Blankenship, R. E., & Govindjee. (2009). A viewpoint: why chlorophyll a?. *Photosynthesis research*, 99, 85-98.
5. Dhaliwal, M. S. (2008). *Handbook of Vegetable Crops*: Kalyani Publishers, New Delhi, India.
6. Havlin, J. L., Beaton, J. D., Tisdale, S. L., & Nelson, W. L. (1999). An introduction to nutrient management. *Soil fertility and fertilizers*, 499.
7. Hiscox, J.D., & Israelstam, G.F. (1979) A Method for Extraction of Chlorophyll from Leaf Tissue without Maceration. *Canadian Journal of Botany*, 57, 1332-1334.
8. Hokmalipour, S., & Darbandi, M. H. (2011). Effects of nitrogen fertilizer on chlorophyll content and other leaf indicate in three cultivars of maize (*Zea mays* L.). *World Applied Sciences Journal*, 15(12), 1780-1785.
9. Indira, S., & Singh, S. J. (2014). Effect of vermicompost and biofertilizer on yield and quality of Rabi onion (*Allium cepa* L.) Cv. Pusa Red. *Agricultural Science Digest-A Research Journal*, 34(2), 144-146.
10. Jackson, M.L. (1967). *Soil Chemical Analysis* Prentice Hall Private Limited, New Delhi.
11. Jayathilake, P. K. S., Reddy, I. P., Srihari, D., Reddy, K. R., & Neeraja, G. (2003). Integrated nutrient management in onion (*Allium cepa* L.). *Tropical Agricultural Research* .15, 1-9
12. K. Mengel, EA. Kirkby (2001). *Principales of Plant Nutrition*, Kluwer Academic Publishers, Dordrecht, Netherland.
13. Nagini, S., Palitti, F., & Natarajan, A. T. (2015). Chemopreventive potential of chlorophyllin: a review of the mechanisms of action and molecular targets. *Nutrition and cancer*, 67(2), 203-211.
14. Prakash, V., Pandey, A. K., & Singh, R. D. (2000). Effect of different levels of nitrogen and FYM on yield and monetary returns of onion varieties. (In) National Symposium on Onion-garlic Production and Post-harvest Management.
15. Radwan, S. M. A., & Hussein, H.F. (2000). Response of onion (*Allium cepa* L.) Plants and associated weeds to biofertilization under some plant mulches. *Ann. Agri. Sci., (Cairo)*, 46 (2): 543-564.
16. Rai, N. and Yadav, D.S. (2005). *Advances in Vegetable Production*. Research Book Centre, New Delhi.
17. Sharma, R. P., Datt, N., & Chander, G. (2009). Effect of vermicompost, farmyard manure and chemical fertilizers on yield, nutrient uptake and soil fertility in okra (*Abelmoschus esculentus*)-onion (*Allium cepa*) sequence in wet temperate zone of Himachal Pradesh. *Journal of the Indian Society of Soil Science*.57(3), 357-361.
18. Sharma, R. P., Datt, N., & Sharma, P. K. (2003). Combined application of nitrogen, phosphorus, potassium and farmyard manure in onion (*Allium cepa*) under high hills, dry temperate conditions of north-western Himalayas. *Indian Journal of Agriculture Sciences*.73(4), 225-227.
19. Singh, A., Singh, S. P., Singh, B. P., & Singh, A. (2002) Effect of VAM and Inorganic Fertilizers on Yield and N, P Content and Uptake in Onion (*Allium Cepa* L.). *Vegetable Science*. 29(2), 161-163.
20. Singh, D. K., Pandey, A. K., Pandey, U. B., & Bhone, S. R. (2001). Effect of farm yard manure combined with foliar application of NPK mixture and micronutrients on growth, yield, and quality of onion. *News Letter - National Horticultural Research and Development Foundation*.21/22, 1, 3/4, 1-7
21. Singh, H., Singh, S., Singh, V., Singh, H., Singh, S., & Singh, V. (1996). Response of onion to nitrogen and sulphur. *Annals Agriculture Research*., 17:441-444.
22. Snell, F.D. & Snell, C.T. (1939). *Colorimetric method of analysis* 3rd Edition, Volume II. D. Von Nostrand Inc., Newyork.
23. Snell, F.D. and Snell, C.T. (1939). *Calorimetric methods of Analysis*, 3rd Ed. 11 Van Nostrand Co. Inc., New York.
24. Soni, A.K. (2005). Effect of crop geometry and fertility levels on growth, yield and quality of Kharif onion (*Allium cepa* L.) Cv. N- 53 in semi-arid conditions. Ph. D. Thesis, RAU, Bikaner.
25. Sreenivas, C., Muralidhar, S., & Rao, M. S. (2000). Vermicompost: a viable component of IPNSS in nitrogen nutrition of ridge gourd. *Annals of Agricultural Research*. 21, 537-542
26. Verma, S., Choudhary, M. R., Yadav, B. L., & Jakhar, M. L. (2013). Influence of vermicompost and Sulphur on growth and yield of garlic (*Allium sativum* L.) Under semi-aridclimate. *Journal of Spices and Aromatic Crops*. 22(1), 20-23.
27. Yadav, R., Dwivedi, D. H., Govind, G., & Maji, S. (2015). Effect of integrated nutrient management on growth and yield of onion (*Allium cepa* L.) Cv. Pusa Madhvi. *Journal Crop and Weed*. 11(1), 49-53.