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## RECENT DEVELOPMENTS IN GLOBAL AND INDIAN FLORICULTURE

Chandana Shivaswamy<sup>1\*</sup> and K.S. Solanki<sup>2</sup>

<sup>1\*</sup>Ph.D. Scholar, Dept. of Floriculture and Landscaping, ICAR-IARI, Pusa New Delhi, 110012,

<sup>2</sup>Ph.D. Scholar, Dept. of Floriculture and Landscape Architecture,  
Junagadh Agricultural University, Junagadh, Gujarat, 392001

\*Corresponding Author E-mail– [chandanasamath@gmail.com](mailto:chandanasamath@gmail.com)

### ABSTRACT

Government of India has identified floriculture as a sunrise industry and accorded it 100% export-oriented status. Owing to steady increase in demand of flowers, floriculture has become one of the important commercial trades in Agriculture. Hence, commercial floriculture has emerged as hi-tech activity that taking place under controlled climatic conditions inside greenhouse. Floriculture in India is being viewed as a high growth Industry. Commercial floriculture is becoming important from the export angle. The liberalization of industrial and trade policies paved the way for development of export-oriented production of cut flowers. The new seed policy had already made it feasible to import planting material of international varieties. It has been found that commercial floriculture is a potential money-spinner, and economical viable agri-business. Indian floriculture industry has been shifting from traditional flowers to cut flowers for export purposes. Traditional flowers are grown in open field condition and have short shelf life which poses many constraints to their exports to distant markets. Therefore, the liberalized economy has given an impetus to the Indian entrepreneurs for establishing export-oriented floriculture units under controlled climatic conditions

**Keywords:** Global, Indian, Export, Floriculture, Trade

### INTRODUCTION

Socio-economic status of people is increasing day by day rapidly at global level where per capita flower consumption also has a positive correlation with it. This has given promotion to the floriculture industry and to the development of new production centres in Asia and Africa which were earlier concentrated in Europe and USA. In Asia, India, China and Thailand are emerging

leading countries with respect to floriculture. In Africa, Kenya, Ecuador, Zimbabwe South Africa, etc. have been moving fast towards flower production. These African countries may beat Indian flora industry, because there are cheap labour, favourable agro climatic condition for naturally ventilated green houses and involvement of Indian entrepreneurs also. In last 20 years, Indian flora industry stepped into international

market and the area under flower cultivation has been expanding continuously. International floriculture trade is US\$ 17 billion, which is increasing 10-15 % annually and is expected to reach US\$ 25 billion by 2025. (3)

## **WORLD FLORICULTURE SCENARIO**

Globally, the export of flowers has increased phenomenally from 8 billion US dollar in 2006 to 13 billion US dollar in 2015. The number of countries reported to have exported flowers in 2006 was 50 which has increased to 118 in the year 2015. The Compound Annual Growth Rate (CAGR) of World's flower export during 2006-2015 is 5 percent. The Netherland is an important producer for cut flowers (54% in Global Market of Production), as well as a key importer from developing countries. Besides being one of the market leaders for cut flowers, the Netherlands are also a main trade hub, especially in the area of Aalsmeer. Every year roughly 1,200 to 1,500 new flowers and plants are bred and cultivated by growers. New types of cut flowers contributed massively to the flower industry. In 2020, cut flowers were the world's 352th most traded product. The trade in cut flowers represents 0.05% of total world trade. In 2020, the top exporters of cut flowers were Netherlands (\$4.01B), Colombia (\$1.42B), Ecuador (\$835M) and Ethiopia (\$191M) and top importers of cut flowers were United States (\$1.68B), Germany (\$1.65B), United Kingdom (\$832M), Netherlands (\$830M) and Russia (\$559M). Between 2019 and 2020, the exports of cut flowers decrease by -3.91% from \$8.79B to \$8.45B. The global floriculture market witnessed a growth rate of 5.9% over the historical period of 2014-21 (5). The International floriculture market is growing 8-10% annually. Globally, Europe, USA and Asia account 90% of the demand of floral products. On average, the international requirement is around Rs. 90,000 crore/year

while demand at the domestic market is at 20-25 %. Hence, the scope to develop in the floriculture industry in India is boundless (3). According to a report by APEDA, 80% of the total import of flowers by the EU takes place during the winter season i.e., November 1 to May 31. Only 20% Flowers are imported in summer (6).

## **INDIAN FLORICULTURE SCENARIO**

Recently, drastic changes took place in Indian floriculture because of liberalization in Indian economy, globalization of trade and privatization, resulted many corporate people have entered in protected cultivation and export of floriculture produces has increased. In India, a tremendous growth in area, production and consumption is being observed in floriculture. Presently, India is on the 18th rank with contributing 0.6 percent share in global floriculture trade. During the last decade, export increased at a CAGR of 4.33 percent. The domestic Indian market is growing at the rate of 25 per cent per year in the country as a whole (4, 2). As per National Horticulture Database (Third Advance Estimates) published by National Horticulture Board, during 2019-20 the area under floriculture production in India is 307 thousand hectares with a production of 2299.93 thousand tonnes loose flowers and 693.87 thousand tonnes cut flowers (1). The states like Kerala, Tamil Nadu, Madhya Pradesh, Karnataka, West Bengal, Andhra Pradesh, Uttar Pradesh, Gujarat and Chhattisgarh have emerged as major floriculture centres in recent times.

The export basket of Indian floricultural products comprises of dry flowers (77.1%), cut flowers (6.1%), bulbs and rhizomes (0.8%), cut foliage (0.02%) and others (15.9%). India has exported 15,695.31 MT of flowers to the world for the worth of 575.98 crores rupees in 2020-21. The strength of floriculture development in India is varied according to

different agroclimatic conditions in the country, availability of manpower and large demand for floricultural products in metropolitan cities. Emphasis has been shifting from traditional flowers to cut flowers for export purposes. The country's first and the only Digital Flower auction Centre is located in Bengaluru. [www.rosebazar.com](http://www.rosebazar.com) is the first and the only online flower auction facility at Bangalore initiated by Karuturi Floritech Ltd. started in March 2000 (4). The floriculture industry comprises the cultivation and trade of cut and loose flowers, cut greens, foliage bedding plants and value-added floriculture products. Some of the important segments of this money spinner industry are cut flowers, loose flowers, protected cultivation, high value flower crops like asiatic ginger lily, protea, heliconia, orchids, bird of paradise, etc., Essential oils of rose, jasmine, tuberose, etc. *Rosa damascena* is exclusively cultivated for extraction of essential oils, rose water, attar, gulkand, etc. in Haldighati (Rajasthan) and some parts of Kannauj (UP) and Himachal Pradesh. Flower seeds and bulbs production, landscape gardening, allied-industries like nurseries, value addition, dry flowers contribute around 70 per cent revenue of total floriculture export. Some major trading sectors of flower are: K. R. Market (Bangalore), Dadar Market in Mumbai, Gultekri Market in Pune, Flower Market in Madurai (TN), Flower Market in Delhi, Jamalpur Flower Market, Ahmedabad Chalai Market in Trivandrum (Kerala), Flower Market in Lucknow (UP), Malikghat bazaar (Calcutta) Chennai (TN) and Jambagh Flower Market (Hyderabad). Similarly, some major online portals (5, 6)

## CONCLUSION

Floriculture products possess 25-30 times more capability to attract foreign exchange earning in comparison to cereals and other agricultural/horticultural products. Floriculture is capable of attracting and retaining large number of progressive farmers/entrepreneurs. Due to ample sunlight and optimum temperature during winter, it does not require artificial lighting or heating for greenhouse production of cut flowers. The industry has continuously been facing several challenges starting from the production phase in terms of small size land holding size, unavailability of basic resources, semiskilled or skilled manpower for harvesting, and post-harvesting techniques and covid time. The government must work out centralized and state-level policies for the development of roads and infrastructure for floriculture units, electric supply, water, cold storage at airport, and customs officials' training for faster processing. The government must also lay down some standard policies and include this in their areas of focus for the encouragement of marginal farmers to get facilitated by easy raw material and suppliers.

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## EFFECT OF HUMIC AND BORIC ACID ON CHILI (*CAPSICUM ANNUM* L.) GROWTH, YIELD AND QUALITY UNDER ARID ZONE OF RAJASTHAN

R. Meena<sup>1</sup>, R. L. Bhardwaj<sup>2</sup>, V. Singh<sup>3</sup>, B. Singh<sup>4\*</sup>, M. Singh<sup>5</sup> and M. Verma<sup>6</sup>

<sup>1,4,5</sup>Ph.D Scholar, Rajasthan College of Agriculture, MPUAT, Udaipur – 313001

<sup>2</sup>Professor, College of Agriculture, Sumerpur, AU, Jodhpur- 342304

<sup>3</sup>Associate Professor, Rajasthan College of Agriculture, MPUAT, Udaipur – 313001

\*Corresponding Author E-mail– [bsgento95@gmail.com](mailto:bsgento95@gmail.com)

### ABSTRACT

The field experiment was carried out during 2017-18 at the Agricultural Research Station, Mandor, Agriculture University, Jodhpur. The main aim of these experiments was to research findings on the vegetative growth, yield, and quality with treatment parameters of the chilli crop. The treatments included humic and boric acid, which were applied as foliar applications with different concentrations at 30, and 60 days after transplanting of the plant. The results obtained strongly indicated that all the treatments and their combinations had significantly influenced the growth, yield, and quality of chilli. Among the various treatments, HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup> was found to be significantly superior in terms of increasing plant height, the number of leaves plant<sup>-1</sup>, leaf area plant<sup>-1</sup>, and the number of primary branches plant<sup>-1</sup>. With regard to fruit yield and quality parameters, the chilli plants sprayed with HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup> also recorded the highest fruit set per cent, the number of fresh fruits per plant, the length of fresh fruit, the diameter of fresh fruit, yield per plant and yield per ha.

**Keywords:** Humic acid, Boric acid, Fruit and Chilli.

### INTRODUCTION

Chilli (*Capsicum annum* L.) is one of the most important commercial vegetable cum spice crops in India. It belongs to the nightshade family, Solanaceae, and has chromosome number 2n = 24. The genus name *Capsicum* is derived from the Latin word “capsa”. Chillies are cultivated mainly in tropical and sub-tropical countries like India, Japan, Mexico, Turkey, the United States of America, and African countries. *Capsicum*

represents a diverse plant group that contains more than 30 species, of which *C. baccatum*, *C. annum*, *C. chinense*, *C. frutescens*, and *C. pubescens* are domesticated and cultivated in different parts of the world. Among the five species of *Capsicum*, *C. annum* is one of the most common cultivated crops worldwide, followed by *C. frutescens*. Chillies have been known since prehistoric times in Peru and are believed to have originated in tropical America. It was introduced in India during the 15th century by the Portuguese.

In India, chilli is grown all over the country in varying agro-climatic zones, but the area under dry chilli is concentrated in the southern states. It is grown extensively throughout the country, both under rainfed and irrigated conditions, in almost all the states, covering an area of 0.83 million hectares with an annual production of 1.87 million tons and a productivity of 2.25 tons per hectare (4). Andhra Pradesh, Telangana, Karnataka, Madhya Pradesh, West Bengal, Odisha, Maharashtra, and Tamil Nadu are the major chilli growing states in India, and Andhra Pradesh is the largest producer of chilli with an area of 0.21 million hectares, an annual production of 0.88 million tons and a productivity of 4.19 tons per hectare. In Rajasthan, red chilli occupies an area of 12318 hectares with an annual production of 18218 MT (3). It is mainly cultivated in the districts of Sawai Madhopur, Jodhpur, Jaipur, Bhilwara, Jalore, and Udaipur, and to a limited extent in Ajmer, Jhalawar, Rajasamand, and Tonk.

## MATERIALS AND METHODS

The experiment was conducted at Agricultural Research Station, Agriculture University, Jodhpur during 2017-18. The experiment location had loamy sand in texture, slightly alkaline in reaction, poor in organic carbon (0.13%), low in available nitrogen ( $174 \text{ kg ha}^{-1}$ ) and phosphorus ( $22.2 \text{ kg ha}^{-1}$ ) but medium in available potassium ( $325 \text{ kg ha}^{-1}$ ). The chilli seedling variety RCh1 was grown from a commercial nursery. Healthy seedlings were selected and transplanted on the 3rd week of June 2017. The full doses of fertilizer are applied @  $100 \text{ kg N}$ ,  $50 \text{ kg P}_2\text{O}_5$  and  $50 \text{ kg K}_2\text{O ha}$  at the time of field preparation. While the remaining dose of nitrogen was applied in two split doses i.e. one month and two months after transplanting.

The different treatment was applied in combination to obtain different observation in the research trial (Table1).

**Table: 1 Treatments**

| Treatments     | Treatment combination doses (mg litre-1) |
|----------------|------------------------------------------|
| T <sub>1</sub> | Humic acid @ 0 + Boric acid @ 0          |
| T <sub>2</sub> | Humic acid @ 0 + Boric acid @ 20         |
| T <sub>3</sub> | Humic acid @ 0 + Boric acid @ 40         |
| T <sub>4</sub> | Humic acid @ 20 + Boric acid @ 0         |
| T <sub>5</sub> | Humic acid @ 20 + Boric acid @ 20        |
| T <sub>6</sub> | Humic acid @ 20 + Boric acid @ 40        |
| T <sub>7</sub> | Humic acid @ 40 + Boric acid @ 0         |
| T <sub>8</sub> | Humic acid @ 40 + Boric acid @ 20        |
| T <sub>9</sub> | Humic acid @ 40 + Boric acid @ 40        |

The RBD design with three replicates was used in an experiment with nine treatments of foliar application, which includes all treatments. Each treatment plot area under open field conditions was  $12 \text{ m}^2$  (3 m length and 4 m width). At the vegetative growth stage, five plants were randomly selected from each plot, were taken 45 days after transplanting for determination of plant height (cm), number of primary branches, number of leaves and green leaf area (GLA  $\text{cm}^2$ ) by use of meter-scale and graph. At the harvest time, chilli fruits were picked weekly through the harvesting period for estimation of yield parameters, i.e. the number basis and fruits basis per plant, total yield per  $\text{m}^2$ . For the fruit quality determination a random sample of 10 fruits from each plot was taken and the average fruit weight, fruit length and diameter were recorded. The root parameter respectively; length of root and number of roots per plant was recorded to the increase production of chilli. The obtained data of experiments were subjected to the statistical analysis of variance procedure and means were compared using the RBD methods at a 5 % level of significance according to Panse and Sukhatme (1985).

## RESULTS AND DISCUSSION

### Plant height (cm) at 45 DAT and last harvest

Among different treatments, the treatment T<sub>9</sub> (HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>) recorded maximum plant height (45.27 cm) at 45 DAT and (70.47 cm) at last harvest, which was at par with treatment T<sub>8</sub> (HA @ 40 mg L<sup>-1</sup> + BA @ 20 mg L<sup>-1</sup>) with 43.20 cm, and (68.20 cm) plant height at 45 days and last harvest respectively. Whereas, all treatments were found least effective but higher than the control. This might be due to enhancement in photosynthetic and other metabolic activities which promote various plant metabolites responsible for cell division and quicker multiplication of cells in the shoot apex and the ultimate result was the maximum plant height of chilli. Similar findings of an increase in plant height by the application of humic and boric acid were also reported by (16, 7, 10 and 15) in chilli.

### Number of leaves plant<sup>-1</sup> at 45 DAT and last harvest

The data pertaining to the number of leaves at 45 DAT and last harvest (Table 2) revealed that among the treatments exhibited significantly superior to control. Among the different treatments of humic and boric acid treatment T<sub>9</sub> (HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>) recorded the maximum number of leaves with 153 and 327 at 45 DAT and last harvest, respectively which was at par with treatment T<sub>8</sub> (HA @ 40 mg L<sup>-1</sup> + BA @ 20 mg L<sup>-1</sup>) with 142 & 302 number of leaves, respectively. However, all the treatments were proved least effective with the numbers of leaves, but higher to control.

### Leaf area plant<sup>-1</sup> (cm<sup>2</sup>) at 45 DAT and last harvest

At the same time data were recorded

with the presented in Table 2. The maximum leaf area was found in treatment T<sub>9</sub> (HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>) which recorded 2238 and 4788 cm<sup>2</sup> leaf area at 45 DAT and last harvest, respectively. It was at par with treatment T<sub>8</sub> (HA @ 40 mg L<sup>-1</sup> + BA @ 20 mg L<sup>-1</sup>) with 2081 & 4422 cm<sup>2</sup>. However, all the treatments were found least effective and these treatments were higher than control with 1207 and 2585 cm<sup>2</sup> leaf area, respectively. This significant increase in the number of leaves and leaf area might be due to better uptake of soil nutrients in the root zone area of plants. These results were also supported by the finding of (1) in tomato, (15) in chilli, and (23) in capsicum.

### Number of primary branches plant<sup>-1</sup> at 45 DAT and last harvest

The data regarding the number of primary branches at 45 DAT and the last harvest are presented in Table 3. The result showed that all treatments were significantly better to control. The treatment T<sub>9</sub> (HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>) recorded the maximum number of primary branches with 9.33 and 13.53 at 45 DAT and last harvest, respectively which was at par with treatment T<sub>8</sub> (HA @ 40 mg L<sup>-1</sup> + BA @ 20 mg L<sup>-1</sup>) with 8.73 & 12.33, respectively. However, all the treatments were found least effective, but better to control with 4.60 and 7.73 number of primary branches plant<sup>-1</sup>. Similar results were also reported by (19, 22) in tomato, (7) in chilli, (9) in bell pepper and (15) in chilli.

### Length of root (cm) at last harvest

Data concerning to length of the root are presented in Table 3. The result showed that the application of humic and boric acid significantly induced the length of roots plant<sup>-1</sup> in all treatments compared to control. The maximum length of root (11.27 cm) was observed by the plants treated with treatment T<sub>9</sub> (HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>) which was at par with treatment T<sub>8</sub> (HA @ 40 mg L<sup>-1</sup> + BA @ 20 mg L<sup>-1</sup>) with 10.87 cm length of root, respectively. However, all the treatments were proved least

effective; although superior to control (7.50 cm).

### Number of roots plant<sup>-1</sup> at last harvest

The data regarding the number of roots are presented in Table 3. All treatments showed a significantly higher number of roots than control. The maximum number of roots plant<sup>-1</sup> (122.93) recorded in T<sub>9</sub> treatment (HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>) which was at par with treatment T<sub>8</sub> (HA @ 40 mg L<sup>-1</sup> + BA @ 20 mg L<sup>-1</sup>) with 110.37 number of root. However, all treatments were found least effective but higher to control (45.40). These results were also supported by the findings of (5) in sugar beet, (20) in strawberry and (11) in tomato.

### Yield parameters

The effect of humic and boric acid on fruit yield parameters of chilli like fruit set (%), fruit drop (%), number of pickings, number of fresh fruit<sup>-1</sup>, length of fresh fruit (cm), the diameter of fresh fruit (cm), the weight of single fresh fruit (g), fruit diameter (cm), yield plant<sup>-1</sup> (g) and yield ha<sup>-1</sup> (q) were studied.

### Fruit set (%)

The data regarding fruit set per cent are presented in Table 4. All treatments showed that the application of humic and boric acid significantly influenced the fruit set compared to control. Among the treatments, maximum fruit set per cent (42.71%) was recorded in treatment T<sub>9</sub> (HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>), which was at par with treatment T<sub>6</sub> (HA @ 20 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>) of 37.27 per cent fruit set. While all treatments were found least effective and superior to the control (20.65%). This might be due to the favourable effect of humic and boric acid on the pollination process, flowering and fruit formation by maintaining cell integrity, improving respiration, enhancement in metabolic activities and uptake of mineral nutrients. Similar results were also obtained by (14) in brinjal, (1) in tomato, (24) in brinjal.

### Fruit drop (%)

The data regarding fruit drop per cent are presented in Table 4. The result showed that all treatments were significantly superior to the control. The minimum fruit drop percentage was recorded by the plants treated with treatment T<sub>9</sub> (HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>) of 5.18 per cent with closely followed by treatment T<sub>6</sub> (HA @ 20 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>) with 5.90 per cent fruit drop, respectively. Whereas, maximum fruit drop (10.27%) was recorded in control.

### Number of fresh fruits plant<sup>-1</sup>

A perusal of data is presented in Table 4. The result exhibited that the application of different levels of humic and boric acid significantly increased the total number of fruits plant<sup>-1</sup> in all treatments than control. Among different treatments, treatment T<sub>9</sub> (HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>) recorded the highest number of fresh fruits (83.28), which was at par with treatment T<sub>6</sub> (HA @ 20 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>) with 80.56 fresh fruits, respectively. While, all treatment was found least effective but better than control (61.15). The increased number of fruits plant<sup>-1</sup> might be due to treated plants being physiologically more active than remaining plants; resulting in more number of flowers and fruit set per cent. These results were confined by the findings of (6, 10) in chilli, (8) in bell pepper, (15) in chilli and (23) in capsicum.

### Length of fresh fruit (cm)

Data concerning the length of fresh fruit are presented in Table 5. The result showed that the application of different levels of humic and boric acid significantly influenced the length of fresh fruit in all treatments compared to control. Among different treatments, T<sub>9</sub> treatment (HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>) recorded the maximum length of fresh fruit (12.66 cm), which was at

par with treatment  $T_8$ , respectively. However, treatment  $T_7$  and  $T_4$  proved least effective with 11.26 and 11.23 cm lengths of fresh fruit, respectively but higher than control (10.33 cm). This might be due to cell divisions and rapid multiplication of cells in reproductive organs and more accumulation of photosynthates in fruits than compared to absolute control. These findings are quite analogous with the finding of (12) in bell pepper, (1) in tomato, (9), (6) and (15) in chilli.

### **Diameter of fresh fruit (cm)**

The data regarding the diameter of fresh fruit are presented in Table 5. The result indicated that there was no significant difference between treatments. However, all the treatments recorded higher fresh fruit diameter than control. Among the treatments, plants treated with the combination of HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup> under  $T_9$  treatment recorded maximum fruit diameter (1.30 cm), which was at par with  $T_8$  treatments which was recorded 1.27 cm diameter of fresh fruit, respectively but higher than control (0.93 cm).

### **Weight of single fresh fruit (g)**

It was evident from the data presented in Table 5. The result exhibited that plants sprayed with different levels of humic and boric acid significantly increased the average fresh fruit weight of chilli than control. Among different treatments, it was observed  $T_9$  treatment (HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>) recorded the highest weight of single fresh fruit (8.91 g), which was at par with  $T_6$  (HA @ 20 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>) of 8.14 g weight of single fresh fruit. Whereas, all treatments were found least effective weight of single fresh fruit, respectively but higher than control (7.15 g). This might be due to the building up of sufficient food stock for developing bigger sized fruits. Similar findings of increased average fruit weight by the application of humic and boric acid were

also reported by (1) in tomato, (6, 15) in chilli and (23) in capsicum.

### **Red chilli yield plant<sup>-1</sup> (g)**

Data pertaining to fruit yield per plant (g) are presented in Table 6. The result indicated that all the humic and boric acids treatments recorded higher yields compared to control. It was observed that under  $T_9$  treatment (HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>) produce maximum fruit yield (742.0 g) plant<sup>-1</sup>, which was at par with treatment  $T_6$  (HA @ 20 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>) with 655.7 g fruit yield plant<sup>-1</sup>, respectively. However, all treatments were found least effective fruit yield, respectively and through superior to control (437.2 g).

### **Red chilli yield ha<sup>-1</sup> (q)**

Data concerning red chilli yield ha<sup>-1</sup> (q) influenced by different levels of humic and boric acid treatments are presented in Table 6. All treatments showed significantly induced red chilli yield ha<sup>-1</sup> than control. The maximum red chilli yield ha<sup>-1</sup> (274.8 q ha<sup>-1</sup>) recorded in treatment  $T_9$  (HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>), which was at par with treatment  $T_6$  (HA @ 20 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>) with 242.8 (q) fruit yield, respectively. However, all treatments were found least effective, respectively but superior to control (161.9 q). These might be due to sufficient enhancement in fruit attributes like fruit set (%), the weight of fresh fruits, length and diameter of fresh fruits and the ultimate result was the maximum yield of chilli. Similar results were reported by (9, 6, 10, 18, 15) in chilli and (23) in Capsicum.

### **Quality parameters**

The effect of different levels of humic and boric acid on quality parameters of chilli such as total soluble solids (%) and acidity (%) was studied. The data of mean value are presented in Table 6.

## TSS (%)

It was evident from Table 6. The result showed that TSS per cent in chilli fruits were significantly increased among the treatments compared to control. Among different treatments, T<sub>9</sub> treatment (HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>) recorded maximum TSS (11.93%) which was at par with treatment T<sub>8</sub> (HA @ 40 mg L<sup>-1</sup> + BA @ 20 mg L<sup>-1</sup>) with 11.60 per cent TSS, respectively. However, all treatments were proved least effective, respectively but higher than control (7.47%).

## Acidity (%)

The data regarding titratable acidity (%) are presented in Table 6. All treatments showed significantly superior to control. The maximum titratable acidity (0.19%) was recorded in T<sub>9</sub> treatment (HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>), which was at par with treatment T<sub>8</sub> (HA @ 40 mg L<sup>-1</sup> + BA @ 20 mg L<sup>-1</sup>) of 0.18 per cent acidity. Whereas all treatments were found least effective, respectively but superior to the control (0.06%), which might have favoured the production of quality fruits. Similar quality parameters were also suggested by (13) in tomato and (12) in chilli.

## Economics of treatments

### Gross return (Rs. ha<sup>-1</sup>)

Gross returns increased with increasing fresh fruit yield of chilli obtained under different treatments are summarized in Table 7. Gross returns were calculated based on the fruit yield of chilli and multiply with the prevailed market price. Close observation of data revealed that the highest gross return (Rs. 274800/- ha<sup>-1</sup>) fetched from the combined application of HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg

L<sup>-1</sup> (T<sub>9</sub> treatment) over control (Rs. 161900/- ha<sup>-1</sup>) and also proved significantly superiority over other treatments.

### Net return (Rs. ha<sup>-1</sup>)

Data in respect of net return under different levels of humic and boric acid treatments have been presented in Table 7. Net returns showed significant variation due to different treatments and were worked out after deducting cost value from gross returns. The data showed that combined application of HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup> (T<sub>9</sub> treatment) at 30 and 60 DAT recorded (Rs. 215002/- ha<sup>-1</sup>) more monetary advantages over control (Rs. 106909/- ha<sup>-1</sup>) and also proved significantly superior over other treatments. However, it showed slight higher (14.87%) over HA @ 20 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup> (T<sub>6</sub> treatment) which gave (Rs. 183024/- ha<sup>-1</sup>) net monetary return.

### Benefit: cost ratio

Data pertaining to the benefit: cost ratio due to different levels of humic and boric acids are presented in Table 7. A perusal of data exhibited a significant increase in the B: C ratio due to different levels of humic and boric acid treatments during experimentation. Among the different treatments, combined application of HA @ 40 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup> (T<sub>9</sub>) showed a significant profitability level in respect of B: C ratio (3.60) and showed its superiority over the rest of humic and boric acid treatments including control (1.94). Similarly, the next best economic option caused prominent improvement in the B: C ratio (3.06) in treatment T<sub>6</sub> (HA @ 20 mg L<sup>-1</sup> + BA @ 40 mg L<sup>-1</sup>). These results were also supported by the findings of (10) in chilli, (19) in tomato and (21) in tomato.

**Table 2: Effect of humic and boric acid on plant height (cm), number of leaves plant-1 and leaf area plant-1 (cm<sup>2</sup>) at 45 DAT and last harvest.**

| Treatments                                                             | Plant height (cm) |              | Number of leaves plant-1 |              | Leaf area plant-1 (cm <sup>2</sup> ) |              |
|------------------------------------------------------------------------|-------------------|--------------|--------------------------|--------------|--------------------------------------|--------------|
|                                                                        | 45 DAT            | Last harvest | 45 DAT                   | Last harvest | 45 DAT                               | Last harvest |
| T <sub>1</sub> (Control)                                               | 32.27             | 54.13        | 82                       | 176          | 1207                                 | 2585         |
| T <sub>2</sub> HA @ 0 mg L <sup>-2</sup> + BA @ 20 mg L <sup>-1</sup>  | 34.53             | 57.27        | 95                       | 193          | 1392                                 | 2834         |
| T <sub>3</sub> HA @ 0 mg L <sup>-1</sup> + BA @ 40 mg L <sup>-1</sup>  | 35.93             | 57.93        | 100                      | 213          | 1470                                 | 3127         |
| T <sub>4</sub> HA @ 20 mg L <sup>-1</sup> + BA @ 0 mg L <sup>-1</sup>  | 38.60             | 62.53        | 111                      | 230          | 1622                                 | 3371         |
| T <sub>5</sub> HA @ 20 mg L <sup>-1</sup> + BA @ 20 mg L <sup>-1</sup> | 40.07             | 63.27        | 117                      | 242          | 1720                                 | 3542         |
| T <sub>6</sub> HA @ 20 mg L <sup>-1</sup> + BA @ 40 mg L <sup>-1</sup> | 40.33             | 64.60        | 123                      | 253          | 1798                                 | 3713         |
| T <sub>7</sub> HA @ 40 mg L <sup>-1</sup> + BA @ 0 mg L <sup>-1</sup>  | 42.07             | 67.87        | 134                      | 283          | 1969                                 | 4153         |
| T <sub>8</sub> HA @ 40 mg L <sup>-1</sup> + BA @ 20 mg L <sup>-1</sup> | 43.20             | 68.20        | 142                      | 302          | 2081                                 | 4422         |
| T <sub>9</sub> HA @ 40 mg L <sup>-1</sup> + BA @ 40 mg L <sup>-1</sup> | 45.27             | 70.47        | 153                      | 327          | 2238                                 | 4788         |
| SEm±                                                                   | 1.62              | 2.28         | 6.85                     | 14.62        | 100.4                                | 214.3        |
| C.D at 5 %                                                             | 4.87              | 6.85         | 20.54                    | 43.83        | 301.2                                | 642.6        |

**Table 3: Effect of humic and boric acid on the number of primary branches plant-1 at 45 DAT and last harvest, length of root (cm) and the number of roots plant-1 at last harvest.**

| Treatments                                                             | Number of primary branches plant <sup>-1</sup> |              | Length of root (cm) at last harvest | Number of roots plant <sup>-1</sup> at last harvest |
|------------------------------------------------------------------------|------------------------------------------------|--------------|-------------------------------------|-----------------------------------------------------|
|                                                                        | 45 DAT                                         | Last harvest |                                     |                                                     |
| T <sub>1</sub> (Control)                                               | 4.60                                           | 7.73         | 7.50                                | 45.40                                               |
| T <sub>2</sub> HA @ 0 mg L <sup>-1</sup> + BA @ 20 mg L <sup>-1</sup>  | 5.34                                           | 8.13         | 8.40                                | 57.93                                               |
| T <sub>3</sub> HA @ 0 mg L <sup>-1</sup> + BA @ 40 mg L <sup>-1</sup>  | 5.73                                           | 8.93         | 8.67                                | 65.47                                               |
| T <sub>4</sub> HA @ 20 mg L <sup>-1</sup> + BA @ 0 mg L <sup>-1</sup>  | 6.27                                           | 9.87         | 9.20                                | 74.87                                               |
| T <sub>5</sub> HA @ 20 mg L <sup>-1</sup> + BA @ 20 mg L <sup>-1</sup> | 7.07                                           | 10.27        | 9.43                                | 86.87                                               |
| T <sub>6</sub> HA @ 20 mg L <sup>-1</sup> + BA @ 40 mg L <sup>-1</sup> | 7.57                                           | 10.73        | 9.87                                | 91.13                                               |
| T <sub>7</sub> HA @ 40 mg L <sup>-1</sup> + BA @ 0 mg L <sup>-1</sup>  | 8.27                                           | 11.87        | 10.67                               | 104.07                                              |
| T <sub>8</sub> HA @ 40 mg L <sup>-1</sup> + BA @ 20 mg L <sup>-1</sup> | 8.73                                           | 12.33        | 10.87                               | 110.37                                              |
| T <sub>9</sub> HA @ 40 mg L <sup>-1</sup> + BA @ 40 mg L <sup>-1</sup> | 9.33                                           | 13.53        | 11.27                               | 122.93                                              |
| SEm±                                                                   | 0.54                                           | 0.68         | 0.41                                | 4.96                                                |
| C.D at 5 %                                                             | 1.60                                           | 2.03         | 1.24                                | 14.88                                               |

**Table 4: Effect of humic and boric acid on fruit set (%), fruit drop (%), number of pickings and number of fresh fruits plant-1.**

| Treatments                                                             | Fruit set (%) | Fruit drop (%) | Number of pickings | Number of fresh fruits plant <sup>-1</sup> |
|------------------------------------------------------------------------|---------------|----------------|--------------------|--------------------------------------------|
| T <sub>1</sub> (Control)                                               | 20.65         | 10.27          | 3.0                | 61.15                                      |
| T <sub>2</sub> HA @ 0 mg L <sup>-1</sup> + BA @ 20 mg L <sup>-1</sup>  | 28.92         | 7.25           | 3.6                | 70.44                                      |
| T <sub>3</sub> HA @ 0 mg L <sup>-1</sup> + BA @ 40 mg L <sup>-1</sup>  | 34.45         | 6.13           | 4.0                | 78.65                                      |
| T <sub>4</sub> HA @ 20 mg L <sup>-1</sup> + BA @ 0 mg L <sup>-1</sup>  | 24.15         | 8.45           | 3.6                | 65.57                                      |
| T <sub>5</sub> HA @ 20 mg L <sup>-1</sup> + BA @ 20 mg L <sup>-1</sup> | 30.05         | 6.57           | 3.6                | 71.55                                      |
| T <sub>6</sub> HA @ 20 mg L <sup>-1</sup> + BA @ 40 mg L <sup>-1</sup> | 37.27         | 5.90           | 4.0                | 80.56                                      |
| T <sub>7</sub> HA @ 40 mg L <sup>-1</sup> + BA @ 0 mg L <sup>-1</sup>  | 28.32         | 7.60           | 3.6                | 68.91                                      |
| T <sub>8</sub> HA @ 40 mg L <sup>-1</sup> + BA @ 20 mg L <sup>-1</sup> | 31.35         | 6.03           | 4.0                | 72.47                                      |
| T <sub>9</sub> HA @ 40 mg L <sup>-1</sup> + BA @ 40 mg L <sup>-1</sup> | 42.71         | 5.18           | 4.0                | 83.28                                      |
| SEm±                                                                   | 2.14          | 0.53           | 0.21               | 3.60                                       |
| C.D at 5 %                                                             | 6.43          | 1.58           | NS                 | 10.80                                      |

**Table 5: Effect of humic and boric acid on length of fresh fruit (cm), diameter of fresh fruit (cm) and weight of single fresh fruit (g).**

| Treatments                                                             | Length of fresh fruit (cm) | Diameter fresh fruit (cm) | Weight of single fresh fruit (g) |
|------------------------------------------------------------------------|----------------------------|---------------------------|----------------------------------|
| T <sub>1</sub> (Control)                                               | 10.33                      | 0.93                      | 7.15                             |
| T <sub>2</sub> HA @ 0 mg L <sup>-1</sup> + BA @ 20 mg L <sup>-1</sup>  | 11.86                      | 1.23                      | 7.56                             |
| T <sub>3</sub> HA @ 0 mg L <sup>-1</sup> + BA @ 40 mg L <sup>-1</sup>  | 12.36                      | 1.28                      | 7.94                             |
| T <sub>4</sub> HA @ 20 mg L <sup>-1</sup> + BA @ 0 mg L <sup>-1</sup>  | 11.23                      | 1.16                      | 7.51                             |
| T <sub>5</sub> HA @ 20 mg L <sup>-1</sup> + BA @ 20 mg L <sup>-1</sup> | 11.76                      | 1.25                      | 7.62                             |
| T <sub>6</sub> HA @ 20 mg L <sup>-1</sup> + BA @ 40 mg L <sup>-1</sup> | 12.43                      | 1.29                      | 8.14                             |
| T <sub>7</sub> HA @ 40 mg L <sup>-1</sup> + BA @ 0 mg L <sup>-1</sup>  | 11.26                      | 1.25                      | 7.58                             |
| T <sub>8</sub> HA @ 40 mg L <sup>-1</sup> + BA @ 20 mg L <sup>-1</sup> | 11.93                      | 1.27                      | 7.73                             |
| T <sub>9</sub> HA @ 40 mg L <sup>-1</sup> + BA @ 40 mg L <sup>-1</sup> | 12.66                      | 1.30                      | 8.91                             |
| SEm±                                                                   | 0.40                       | 0.06                      | 0.31                             |
| C.D at 5 %                                                             | 1.20                       | 0.18                      | 0.93                             |

**Table 6: Effect of humic and boric acid on yield plant<sup>-1</sup> (g), yield ha<sup>-1</sup>(q), TSS (%) and acidity (%).**

| Treatments                                                             | Yield plant <sup>-1</sup> (g) | Yield ha <sup>-1</sup> (q) | TSS (%) | Acidity (%) |
|------------------------------------------------------------------------|-------------------------------|----------------------------|---------|-------------|
| T <sub>1</sub> (Control)                                               | 437.2                         | 161.9                      | 7.47    | 0.06        |
| T <sub>2</sub> HA @ 0 mg L <sup>-1</sup> + BA @ 20 mg L <sup>-1</sup>  | 532.5                         | 197.2                      | 8.27    | 0.07        |
| T <sub>3</sub> HA @ 0 mg L <sup>-1</sup> + BA @ 40 mg L <sup>-1</sup>  | 624.4                         | 231.2                      | 8.50    | 0.08        |
| T <sub>4</sub> HA @ 20 mg L <sup>-1</sup> + BA @ 0 mg L <sup>-1</sup>  | 492.4                         | 182.3                      | 9.40    | 0.10        |
| T <sub>5</sub> HA @ 20 mg L <sup>-1</sup> + BA @ 20 mg L <sup>-1</sup> | 545.2                         | 201.9                      | 9.53    | 0.11        |
| T <sub>6</sub> HA @ 20 mg L <sup>-1</sup> + BA @ 40 mg L <sup>-1</sup> | 655.7                         | 242.8                      | 10.33   | 0.13        |
| T <sub>7</sub> HA @ 40 mg L <sup>-1</sup> + BA @ 0 mg L <sup>-1</sup>  | 522.3                         | 193.4                      | 11.47   | 0.16        |
| T <sub>8</sub> HA @ 40 mg L <sup>-1</sup> + BA @ 20 mg L <sup>-1</sup> | 560.2                         | 207.4                      | 11.60   | 0.18        |
| T <sub>9</sub> HA @ 40 mg L <sup>-1</sup> + BA @ 40 mg L <sup>-1</sup> | 742.0                         | 274.8                      | 11.93   | 0.19        |
| SEm±                                                                   | 42.46                         | 15.73                      | 0.23    | 0.007       |
| C.D at 5 %                                                             | 127.2                         | 47.15                      | 0.70    | 0.02        |

**Table 7: Economics of treatments**

| Treatments                                                             | Yield q ha <sup>-1</sup> | Cost of cultivation (including the cost of treatment) Rs. ha <sup>-1</sup> | Gross return Rs. ha <sup>-1</sup> | Net return Rs. ha <sup>-1</sup> | Benefit: cost ratio |
|------------------------------------------------------------------------|--------------------------|----------------------------------------------------------------------------|-----------------------------------|---------------------------------|---------------------|
| T <sub>1</sub> (Control)                                               | 161.9                    | 54991                                                                      | 161900                            | 106909                          | 1.94                |
| T <sub>2</sub> HA @ 0 mg L <sup>-1</sup> + BA @ 20 mg L <sup>-1</sup>  | 197.2                    | 58497                                                                      | 197200                            | 138703                          | 2.37                |
| T <sub>3</sub> HA @ 0 mg L <sup>-1</sup> + BA @ 40 mg L <sup>-1</sup>  | 231.2                    | 59753                                                                      | 231200                            | 171447                          | 2.87                |
| T <sub>4</sub> HA @ 20 mg L <sup>-1</sup> + BA @ 0 mg L <sup>-1</sup>  | 182.3                    | 58513                                                                      | 182300                            | 123787                          | 2.12                |
| T <sub>5</sub> HA @ 20 mg L <sup>-1</sup> + BA @ 20 mg L <sup>-1</sup> | 201.9                    | 58519                                                                      | 201900                            | 143381                          | 2.45                |
| T <sub>6</sub> HA @ 20 mg L <sup>-1</sup> + BA @ 40 mg L <sup>-1</sup> | 242.8                    | 59776                                                                      | 242800                            | 183024                          | 3.06                |
| T <sub>7</sub> HA @ 40 mg L <sup>-1</sup> + BA @ 0 mg L <sup>-1</sup>  | 193.4                    | 58535                                                                      | 193400                            | 134865                          | 2.30                |
| T <sub>8</sub> HA @ 40 mg L <sup>-1</sup> + BA @ 20 mg L <sup>-1</sup> | 207.4                    | 59792                                                                      | 207400                            | 147608                          | 2.47                |
| T <sub>9</sub> HA @ 40 mg L <sup>-1</sup> + BA @ 40 mg L <sup>-1</sup> | 274.8                    | 59798                                                                      | 274800                            | 215002                          | 3.60                |

\*Market selling price Rs. 1000 q<sup>-1</sup>

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## ESTIMATION OF COMPOUND GROWTH RATE USING NONLINEAR GROWTH MODELS FOR AREA AND PRODUCTION OF CABBAGE AND CAULIFLOWER IN HARYANA

Vikash Kumar Sumit, Manoj Kumar\* and Sarita Rani

Department of Mathematics and Statistics, Chaudhary Charan Singh Hisar Agriculture University

Hisar-125004 (Haryana), India

\*Corresponding Author E-mail– [m25424553@gmail.com](mailto:m25424553@gmail.com)

### ABSTRACT

Nonlinear growth models are widely used in the study for growth pattern of various entities. For fitting the data to these models, we require initial values for different iterative procedures to get the final estimate of coefficients. These are usually taken up by visualizing the data, results from earlier experiments or a close guess. In this study, an attempt has been made to figure out the initial values of coefficients of nonlinear growth models and computation of compound growth rates for Logistic, Gompertz and Monomolecular model. So, an empirical study was conducted on area and production of Cabbage and Cauliflower in Haryana from 1992-93 to 2018-19 to get initial values and computation of growth rates by using non-linear growth models. The initial values for different models were obtained using method of three selected points, method of partial sums and Yule's method in RStudio software. The SPSS software was used to get the final parameters of above models which uses Levenberg-Marquardt algorithm. Residual analysis and goodness of fit tests was used to decide the best fitted model. Cabbage and Cauliflower area was best fitted with Gompertz model with average CAGR of 8.59% and its production was fitted with Monomolecular model with CAGR of 9.90%.

**Keywords:** Logistic model, Gompertz model, Monomolecular model, Initial values, CAGR

### INTRODUCTION

Agriculture is a vital sector of Haryana economy and most of the population is directly or indirectly dependent on agriculture and its allied activities. Horticulture in recent times has gained huge status due to increased productivity, generating employment and in enhancing exports. Horticulture is also a major diversified activity for nutritional security. Haryana is emerging as one of the leading states in the field of Horticulture in India, where almost all type of fruits, vegetables, spices, mushroom & flowers are being grown. Horticultural crops covered 4.78 lakh hectares area which is 7.27 % of the gross

cropped area (GCA) of the State. Production from horticultural crops in the state was 80.67 lakh metric tons during the year 2019-20. Out of the total area under horticultural crops, around 83 % was under vegetables & rest under fruits, spices, and mushrooms. Total area under vegetable crops was 3.97 lakh hectares in 2019-20 with the production of 67.38 lakh ton. In 2010-11, vegetable crops covered 3.46 lakh hectares area and had production of 46.49 lakh ton (Economic Survey of Haryana 2020-21). There is a 15 % and 45 % increase in the area and production of vegetable crops in Haryana in the last decade. The requirement for fresh vegetables has increased manifold in neighbouring states and

union territories. Horticulture Department of Haryana has vision “to make Haryana Modern Fruit and Vegetable Cultivation State with a vision to lead in domestic and export market” (Horticulture Department, Government of Haryana 2021).

The growth rate is defined as a percentage increase or decrease of a specific variable within a given time period. In Economics, compound annual growth rate (CAGR) is the rate of return that would be required for an investment to grow from its beginning balance to its ending balance, assuming the profits were reinvested at the end of each year of the investment's lifespan as reported by (1). It is equivalent to the more generic exponential growth rate when the exponential growth interval is one year (2).

The growth rate is one of the prime considerations in agriculture. Study of time series data of the area, production and productivity of different crops and computing their growth rate helps in analysing the growth pattern of various crops, the formulation, modification and execution of agricultural policies which influence farm decisions, planning of future operations, comparison of current performance with the expected ones, prediction or estimation or forecasting, comparing the changes in the values at different times or places, etc. Many studies have been done by researchers (13,7,10) for fitting the best nonlinear growth model and compute the compound growth rate of various crops and other biological entities. Computation of growth rates by traditional approaches had several serious gaps reported by ((11) and (5). They observed the weaknesses in the old procedure of estimating regression parameters after logarithmic transformation of the compound growth rate formula or the famous Malthusian model. Considering the above the study has been undertaken to find out the best fitted nonlinear model for Cabbage & Cauliflower in Haryana and estimate the compound annual growth rate for its area and production.

## MATERIALS AND METHODS

The data for the area and production of Cabbage & Cauliflower for the period 1992-93 to 2018-19 in Haryana was collected from the Horticulture Department, Government of Haryana. The sources like Economic Survey of Haryana, Statistical Abstract of Haryana, and Horticulture Department (Government of India) have been used to fill the unclear values. In some cases, linear interpolation between two known points was used to fill the ambiguous data points. In this method a straight line between the two known points around the missing point is created and then using that line we impute the missing value (Linear... 2021).

The realistic nonlinear growth models have been used for the study as mentioned in (5) are:

### Logistic Model

It presumes that growth rate is proportional to the product of the present size and the future amount of growth, being some limiting growth value.

Differential equation for this model is,

$$\frac{dy}{dt} = \frac{ry(p-y)}{P}, r > 0$$

Integral equation for above model is

where  $r$  is intrinsic growth rate,  $q$  is function of initial value or  $\frac{p-y(0)}{y(0)}$ , and  $p$  is

carrying capacity. Logistic curve is S shaped and is symmetric about its point of inflection.

### Gompertz Model

This model has differential equation,  $\frac{dy}{dt} = ry \log\left(\frac{p}{y}\right)$  which yields integral equation

upon solving as  $y = pe^{-qe^{-rt}}$ . It also has S-shaped curve like the logistic but not symmetrical about its point of inflection.

### Monomolecular Model

It assumes that the rate of growth at a particular time  $t$  is directly proportional to the amount of growth yet to be achieved.

Differential equation of monomolecular

model is  $\frac{dy}{dt} = r(p - y)$ . Solving this equation gives the integral equation  $y = p(1 - qe^{-rt})$ . It has no point of inflection.

The above deterministic models are converted to statistical models by adding an error term on the right-hand side. It is not possible to solve the intrinsically nonlinear equations exactly. The only option to solve such equations is to use the iterative procedures. The most popular procedure is Levenberg-Marquardt's method. It approximately always converges and does not slow down at the latter part of the iterative process ((11) and Chandran 2005).

The details of this procedure in brief are:

Let the model be

$$y_i = f(t_i, \theta) + \epsilon_i, i = 1, 2, \dots, n$$

where  $y_i$  and  $t_i$  are respectively the observations of explanatory and response variables,  $\theta = (\theta_1 \theta_2 \dots \theta_p)'$  are parameters, and error terms  $\epsilon_i$  are independent and follow  $N(0, \sigma^2)$ . The error or residual sum of squares is given by:  $S(\theta) = \sum_{i=1}^n [y_i - f(t_i, \theta)]^2$

Let  $\theta_0 = (\theta_{10} \theta_{20} \dots \theta_{p0})'$  be the vector of initial parameter values. Then the successive estimates are given by:

$$(H + \Delta I)(\theta_0 - \theta_1) = g, \text{ where } g = \left[ \frac{\partial S(\theta)}{\partial \theta} \right]_{\theta=\theta_0},$$

$$H = \left[ \frac{\partial^2 S(\theta)}{\partial \theta \partial \theta'} \right]_{\theta=\theta_0}, \text{ I is identity}$$

identity matrix, and  $\Delta$  is suitable multiplier.

The above complex task can easily be performed by using SPSS[SPSS (12)] which has NLR command.

## Methods Used to Obtain The Initial Values

Method of three selected points - The three equidistant ordinates  $y_1, y_2$  and  $y_3$  are obtained by least square method. The sum or average of more than one neighbouring and equidistant values can also be taken. These

ordinate values can be used to get three equations with three unknown parameters. It can be used in all the above models (Gupta and Kapoor 2007).

Let  $y_t = a + b.c^t$  be the modified exponential curve, where  $a > 0$ ,  $y_t$  is time series data at time  $t$  and  $a, b, c$  are parameters of the curve. If  $y_1, y_2$  and  $y_3$  are the three equidistant values at time  $t_1, t_2$  and  $t_3$  and respectively. Since  $t_2 - t_1 = t_3 - t_2$ , we obtain three equations:

$$y_1 = a + b.c^{t_1}, y_2 = a + b.c^{t_2}, y_3 = a + b.c^{t_3}$$

Solving these equations will yield our initial values as

$$c = \left[ \frac{y_3 - y_2}{y_2 - y_1} \right]^{\frac{1}{t_2 - t_1}}, b = \left[ \frac{(y_2 - y_1)^2}{y_3 - 2y_2 + y_1} \right]$$

$$\left[ \frac{y_2 - y_1}{y_3 - y_2} \right]^{\frac{t_1}{t_2 - t_1}}, a = \left[ \frac{y_1 \cdot y_3 - y_2^2}{y_3 - 2y_2 + y_1} \right]$$

## Method of partial sums

The time-series data are first divided into three equal parts each containing consecutive values of  $t$ . The summation of these equal parts can be used to obtain three equations. Solving them can help in getting initial values. Mainly used for Gompertz and Monomolecular model.

$$\text{Let } S_1 = \sum_{t=1}^k y_t, S_2 = \sum_{t=k+1}^{2k} y_t, S_3 = \sum_{t=2k+1}^{3k} y_t$$

Putting the value of  $y_t = a + b.c^t$  and solving further we get,  $\sum_{t=1}^k (a + b.c^t) =$

$$k.a + b(c + c^2 + \dots + c^k) = K.a + b.c \left[ \frac{c^k - 1}{c - 1} \right]$$

$$\text{Likewise, } S_2 = K.a + b.c^{k+1} \left[ \frac{c^k - 1}{c - 1} \right],$$

$$S_3 = K.a + b.c^{2k+1} \left[ \frac{c^k - 1}{c - 1} \right]$$

On solving above equations, we get,

$$c = \left[ \frac{S_3 - S_2}{S_2 - S_1} \right]^{\frac{1}{k}}, b = \left[ \frac{(c-1).(S_2 - S_1)^3}{c.(S_3 - 2.S_2 + S_1)} \right],$$

$$a = \frac{1}{k} \left[ \frac{S_1.S_3 - S_2^2}{S_3 - 2.S_2 + S_1} \right]$$

### Yule's Method

If the value of  $k$  is approximately known or found by other methods, then the logistic curve equation has two parameters  $a$  and  $b$  and two variables  $t$  and  $y_t$ . Therefore, the principles of least squares can be used to estimate  $a$  and  $b$ .

### Procedure For Getting Initial Values For Logistic Model

(1) Three points  $(t_9, y_9)$ ,  $(t_{18}, y_{18})$  and  $(t_{27}, y_{27})$  are selected from fitting the data to straight line curve.

(2) Substitute the points in model ignoring the residual term, we get

$$(3) \quad y_9 = \frac{p}{1 + q(e^{-r.t_9})}, y_{18} = \frac{p}{1 + q(e^{-r.t_{18}})},$$

$$y_{27} = \frac{p}{1 + q(e^{-r.t_{27}})}$$

$$(4) \because t_{18} - t_9 = t_{27} - t_{18}$$

(5) Solving these equations will give

$$p = \frac{[y_{18}^2(y_9 + y_{27}) - 2(y_9)(y_{18})(y_{27})]}{[y_{18}^2(y_9)(y_{27})]}$$

(6) Now using Yule's method to get  $a$  and  $r$ .

$$(7) \quad y_t = \frac{p}{1 + q(e^{-rt})} \Rightarrow \frac{p}{y_t} = 1 + q(e^{-rt})$$

$$\Rightarrow \frac{p}{y_t} - 1 = q(e^{-rt})$$

$$(8) \ln \left( \frac{p}{y_t} - 1 \right) = \ln(q) - r.t \quad (9) C = B + A.t$$

$$(10) \text{ where } C = \ln \left( \frac{p}{y_t} - 1 \right),$$

$$B = \ln(q), A = -r$$

### Procedure For Getting Initial Values For Gompertz Model

(1) The error term in model  $y_t = p.e^{-q.e^{-r.t}}$  is ignored.

(2) Taking  $\ln$  on both sides i.e.  $\ln(y_t) = \ln(p) - q.e^{-rt}$

(3) Above equation can be written as  $y_t = a + b.c^t$

(4) where

(5) Using method of three selected points or partial sums, we find  $a$ ,  $b$  and  $c$ .

(6) Using back transformation we get,  $p = e^a$ ,  $q = -b$ ,  $r = -\ln(c)$

### Procedure For Getting Initial Values For Monomolecular Model

(1) Ignoring the error term in  $y_t = p(1 - qe^{-rt})$ .

(2) Writing the model in the form or  $y_t = p - (p.q.e^{-rt})$  or  $y_t = a + b.c^t$

(3) where  $a = p$ ,  $b = -p.q$ ,  $c = e^{-r}$

(4) Using method of three selected points or partial sums, we get values of  $a$ ,  $b$  and  $c$ .

(5) Parameters are obtained by reverse transformation as  $p = a$ ,  $q = -\frac{b}{p}$ ,  $r = -\ln(c)$ .

RStudio (RStudio Team 2020) was used to obtain initial values.

### Goodness of Fit For A Nonlinear Growth Model

#### Coefficient of determination

It is given by the formula

$$R^2 = 1 - \left[ \frac{\sum_{i=1}^n (y_i - y_l)^2}{\sum_{i=1}^n (y_i - \bar{y})^2} \right]$$

The value of  $R^2$  lies between 0 and 1. The model is said to be best fit if it has  $R^2$  value close to 1. It tells the amount of variability in response variable that can be explained by explanatory variables.

Mean squared error (MSE) -It is defined as

the average of the squared difference between estimated and observed values. Mathematically it can be written as: -

$$MSE = \frac{1}{n} \left[ \sum_{i=1}^n (y_i - \bar{y}_i)^2 \right]$$

Root mean square error (RMSE) -It is calculated as  $RMSE = \sqrt{\frac{1}{n} \left[ \sum_{i=1}^n (y_i - \bar{y}_i)^2 \right]}$ . Model with lowest RMSE is considered as best fitted model.

Mean absolute error (MAE) -It is the average of absolute deviation of observed and predicted values.  $MAE = \frac{1}{n} \left[ \sum_{i=1}^n |y_i - \bar{y}_i| \right]$

### Residual Analysis

The two crucial assumptions made in the model are:

- (1)Error terms are independent.
- (2)Error terms are normally distributed.

Validity of these assumptions has been tested by Run test and Shapiro-Wilk test, respectively in SPSS (SPSS 2007).

### Computation of Compound Growth Rates

The growth rate which is given by  $\frac{d[In(y)]}{dt}$  or  $\frac{1}{y} \left( \frac{dy}{dt} \right)$ . The annual growth rate of nonlinear models for each period  $(t_i, t_{i+1}), i = 0, 1, \dots, n-1$  where represent data points is given by:

$$R \text{ (Logistic)} = r \left[ 1 - \left( \frac{y_t}{p} \right) \right]$$

$$R \text{ (Gompertz)} = r \left[ \ln \left( \frac{p}{y_t} \right) \right]$$

$$R \text{ (Monomolecular)} = r \left[ \left( \frac{p}{y_t} \right) - 1 \right]$$

By taking arithmetic mean, compound growth rate over a given period can be computed.

## RESULTS AND DISCUSSION

### Results

The time series data for the area and production of Cabbage & Cauliflower crop in Haryana from 1992-93 to 2018-19 has been given in Table1.

**Table .Area (in hectares) and Production (in tons) of Cabbage & Cauliflower crop in Haryana from 1992-93 to 2018-19**

| Year    | Area  | Production |
|---------|-------|------------|
| 1992-93 | 8000  | 135440     |
| 1993-94 | 8500  | 157400     |
| 1994-95 | 9800  | 182000     |
| 1995-96 | 10350 | 187650     |
| 1996-97 | 10800 | 191500     |
| 1997-98 | 11500 | 173700     |
| 1998-99 | 13400 | 256400     |
| 1999-00 | 18000 | 348500     |
| 2000-01 | 18436 | 345441     |
| 2001-02 | 19672 | 297105     |
| 2002-03 | 21410 | 335370     |
| 2003-04 | 26869 | 399325     |
| 2004-05 | 27375 | 434123     |
| 2005-06 | 33336 | 474992     |
| 2006-07 | 41151 | 590082     |
| 2007-08 | 35580 | 502526     |
| 2008-09 | 37027 | 714540     |
| 2009-10 | 37929 | 705947     |
| 2010-11 | 44059 | 782532     |
| 2011-12 | 44011 | 854029     |
| 2012-13 | 45257 | 762640     |
| 2013-14 | 45096 | 767621     |
| 2014-15 | 46895 | 731863     |
| 2015-16 | 57168 | 889506     |
| 2016-17 | 48868 | 835033     |
| 2017-18 | 61089 | 1041447    |
| 2018-19 | 65187 | 1315082    |

**Source: Horticulture Department, Government of Haryana (2019)**

Table2. depicts the initial values of parameters of nonlinear growth models for area and production of Cabbage & Cauliflower crop. Method of three selected points and Yule's method was employed for Logistic model, while method of partial sums was used for Gompertz and Monomolecular model.

**Table . Initial values of parameters of nonlinear growth models for area (in hectares) and production (in tons) of Cabbage & Cauliflower crop in Haryana from 1992-93 to 2018-19**

| Initial value of parameters | Logistic Model | Gompertz Model | Monomolecular model |            |            |            |
|-----------------------------|----------------|----------------|---------------------|------------|------------|------------|
|                             | Area           | Production     | Area                | Production | Area       | Production |
|                             | 79936.00       | 1365336.00     | 89396.96            | 1910837.00 | -559866.00 | -672348.60 |
|                             | 10.91          | 16.78          | -11.56              | -14.20     | 0.0057     | 0.98       |
|                             | 0.13           | 0.16           | 0.07                | 0.06       | -0.0036    | -0.03      |

Table 3. shows the final values of parameters of nonlinear growth models for area and production of Cabbage & Cauliflower crop which had obtained from nonlinear regression analysis using NLR option in SPSS.

**Table 3. Final values of parameters of nonlinear growth models for area (in hectares) and production (in tons) of Cabbage & Cauliflower crop in Haryana from 1992-93 to 2018-19**

| Final value of parameters | Logistic Model | Gompertz Model | Monomolecular model |            |            |            |
|---------------------------|----------------|----------------|---------------------|------------|------------|------------|
|                           | Area           | Production     | Area                | Production | Area       | Production |
|                           | 74344.69       | 1656498.08     | 106348.65           | 3079826.26 | 6814795.00 | -611962.54 |
|                           | 9.97           | 13.06          | 2.96                | 3.45       | 1.00       | 1.11       |
|                           | 0.14           | 0.12           | 0.06                | 0.04       | 0.0003     | -0.03      |

The assumption of independence of error terms for different models has been analyzed using Run test in SPSS. Normality test have been performed using Shapiro-Wilk test in SPSS. Results of both the tests has been given in Table 4. Z is the statistic for Run test i.e., test for independence of error terms. Not significant value in Run test suggests that error terms are independent while in Shapiro-Wilk test it tells error terms are normally distributed. Model which had minimum mean of residuals and independent

error terms were given priority in selection of best fitted model.

**Table 4. Test of independence and normality of nonlinear growth models for area (in hectares) and production (in tons) of Cabbage & Cauliflower crop in Haryana from 1992-93 to 2018-19**

|                         | Logistic Model | Gompertz Model | Monomolecular model |            |         |            |
|-------------------------|----------------|----------------|---------------------|------------|---------|------------|
|                         | Area           | Production     | Area                | Production | Area    | Production |
| Mean                    | -60.68         | -1961.46       | -1.48               | -714.78    | 14.75   | 0.00       |
| S.D.                    | 3216.71        | 85460.34       | 3099.46             | 83363.73   | 3325.83 | 82182.58   |
| No. of runs             | 15.00          | 13.00          | 13.00               | 11.00      | 9.00    | 11.00      |
| Z                       | 0.19NS         | -0.39NS        | 0.33NS              | -1.13NS    | -1.73NS | -1.13NS    |
| Shapiro-Wilk test value | 0.95NS         | 0.96NS         | 0.97NS              | 0.97NS     | 0.96NS  | 0.98NS     |

NS Not significant at 0.01% level of significance

Goodness of fit tests for model comparison has been shown in Table 5. Model with high R<sup>2</sup> and low RMSE and MAE is desirable.

**Table 5. Model comparison of fitted models using goodness of fit tests**

|                | Logistic Model | Gompertz Model | Monomolecular model |            |         |            |
|----------------|----------------|----------------|---------------------|------------|---------|------------|
|                | Area           | Production     | Area                | Production | Area    | Production |
| R <sup>2</sup> | 0.97           | 0.93           | 0.97                | 0.93       | 0.96    | 0.93       |
| RMSE           | 3157.16        | 83885.75       | 3041.52             | 81808.52   | 3263.70 | 80646.32   |
| MAE            | 2281.49        | 60393.75       | 2258.62             | 61213.34   | 2655.40 | 62584.15   |

On the basis of Table 4. and Table 5. it was found that Gompertz and Monomolecular model were best fitted model for the area and production of Cabbage & Cauliflower, respectively. Based on the fitted model, predicted area and production of studied vegetable crop along with compound annual growth rate has been put in Table 6. The average CAGR for Cabbage & Cauliflower crop's area and production were 8.59% and 9.90%, respectively.

**Table 6. Predicted area and production and their compound annual growth rate of Cabbage & Cauliflower crop on the basis of best fitted model**

| Time<br>(in years) | Predicted<br>Area<br>(in<br>hectares) | Compound<br>Annual<br>Growth<br>Rate<br>in area | Predicted<br>Production<br>(in tons) | Compound Annual<br>Growth<br>Rate<br>in<br>production |
|--------------------|---------------------------------------|-------------------------------------------------|--------------------------------------|-------------------------------------------------------|
| 1992-93            | 6574.06                               | 0.1701                                          | 90457.26                             | 0.2677                                                |
| 1993-94            | 7753.23                               | 0.1600                                          | 115094.94                            | 0.2178                                                |
| 1994-95            | 9054.93                               | 0.1505                                          | 140596.79                            | 0.1845                                                |
| 1995-96            | 10478.34                              | 0.1416                                          | 166993.13                            | 0.1608                                                |
| 1996-97            | 12021.04                              | 0.1332                                          | 194315.34                            | 0.1430                                                |
| 1997-98            | 13679.07                              | 0.1253                                          | 222595.88                            | 0.1293                                                |
| 1998-99            | 15447.03                              | 0.1179                                          | 251868.37                            | 0.1182                                                |
| 1999-00            | 17318.28                              | 0.1109                                          | 282167.61                            | 0.1092                                                |
| 2000-01            | 19285.08                              | 0.1043                                          | 313529.61                            | 0.1018                                                |
| 2001-02            | 21338.76                              | 0.0981                                          | 345991.65                            | 0.0954                                                |
| 2002-03            | 23469.96                              | 0.0923                                          | 379592.30                            | 0.0901                                                |
| 2003-04            | 25668.77                              | 0.0868                                          | 414371.51                            | 0.0854                                                |
| 2004-05            | 27924.98                              | 0.0817                                          | 450370.62                            | 0.0813                                                |
| 2005-06            | 30228.18                              | 0.0769                                          | 487632.41                            | 0.0777                                                |
| 2006-07            | 32568.02                              | 0.0723                                          | 526201.17                            | 0.0746                                                |
| 2007-08            | 34934.26                              | 0.0680                                          | 566122.76                            | 0.0717                                                |
| 2008-09            | 37316.97                              | 0.0640                                          | 607444.60                            | 0.0692                                                |
| 2009-10            | 39706.62                              | 0.0602                                          | 650215.83                            | 0.0669                                                |
| 2010-11            | 42094.16                              | 0.0566                                          | 694487.28                            | 0.0649                                                |
| 2011-12            | 44471.10                              | 0.0533                                          | 740311.57                            | 0.0630                                                |
| 2012-13            | 46829.54                              | 0.0501                                          | 787743.16                            | 0.0613                                                |
| 2013-14            | 49162.26                              | 0.0471                                          | 836838.44                            | 0.0597                                                |
| 2014-15            | 51462.70                              | 0.0443                                          | 887655.76                            | 0.0582                                                |
| 2015-16            | 53724.96                              | 0.0417                                          | 940255.51                            | 0.0569                                                |
| 2016-17            | 55943.86                              | 0.0392                                          | 994700.22                            | 0.0557                                                |
| 2017-18            | 58114.83                              | 0.0369                                          | 1051054.61                           | 0.0545                                                |
| 2018-19            | 60233.97                              | 0.0347                                          | 1109385.65                           | 0.0535                                                |

## DISCUSSION

The compound growth rate of various crops varies with different geographical and climatic conditions. Other factor which indirectly affect this variation is demand and supply of various commodities at different locations. The idea of growth rate helps the policy makers in formulation and implementation of crop specific agriculture schemes. The three popular nonlinear growth models viz. Logistic, Gompertz and Monomolecular were chosen for the study after several readings of related

literatures in different crops at various locations around the globe. Two methods for estimation of CAGR parameters were available in literature. The conventional approach uses the linear transformation of Malthus model then utilizes the concept of linear regression to estimate its parameters. The modern methodology uses the nonlinear growth models and iterative procedure to estimate the coefficients. The most popular and widely used iterative procedure is Levenberg-Marquardt algorithm. SPSS software uses the same. In this study, SPSS software has been used to estimate model parameters. The important requirement for analyzing the data in SPSS is the initial or starting values of the model parameters. For this, there is no rigid formula or procedure available in literature. The method of three selected points, method of partial sums and Yule's method was used to obtain the initial values rather than taking a guess or by visualizing the data. Secondary data of Cabbage & Cauliflower crop from 1992-93 to 2018-19 was collected and refined using linear interpolation. The R Software was used to find the initial values and rest analytics were done using SPSS.

Cabbage and Cauliflower area was best fitted with Gompertz model with average CAGR of 8.59%, while production was fitted with Monomolecular model and had average compound growth rate of 9.90%. Similar study have been performed by different researchers viz. (13), (9) and (15) in variety of crops. But in those studies method for finding the initial values were not clear. (10) studied the behaviour of the growth models in Guava fruit. They found that Monomolecular was the best fit for the production of Guava fruit in the Hisar and Yamunanagar districts, while Logistic was in Kurukshetra district and Haryana state as a whole. The annual growth rate of Guava production for Hisar, Kurukshetra, Yamunanagar districts and

Haryana as a whole was 7.93%, 7.62%, 8.82% and 10.20%, respectively.

## CONCLUSION

In this paper method of three selected points, method of partial sums and Yule's method was used to obtain the initial values rather than taking a guess or by visualizing the data. All the computation was performed in R software or Excel. The SPSS software was used to get the final parameters of above models which uses Levenberg-Marquardt algorithm. Residual analysis and goodness of fit tests was used to decide the best fitted model. Cabbage and Cauliflower area was best fitted with Gompertz model with average CAGR of 8.59% and its production was fitted with Monomolecular model with CAGR of 9.90%.

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## CULTIVATION OF KING OYSTER MUSHROOM (*PLEUROTUS ERYNGII*) A SUSTAINABLE WAY FOR AGRO-WASTE MANAGEMENT

Himanshu, S.N. Sharma, Sandeep Kumar, Jitendra Kumar and Punjab Singh Malik\*

Department of Botany, Meerut College, Meerut-250001  
Uttar Pradesh, India

\*Corresponding Author E-mail– [punjabmalik@gmail.com](mailto:punjabmalik@gmail.com)

### ABSTRACT

Globally, food security is an emerging issue due to the increase of population and shrinkage of agricultural land. *Pleurotus eryngii* mushroom cultivation is one of the most efficient and economically viable tools for agro and industrial wastes management. Availability of agro-wastes and labours in Asian countries are conducive factors for this conversion of wastes into quality protein food. *P.eryngii* is a saprophytic fungal species that can be grown on different agro-wastes having lignocellulosic organic matter. It has also been considered as an important low energy food with high nutritional value, low fat, long shelf life and also used as medicine for different diseases of human beings. In this article, we have reviewed the possible aspects of sustainability of agro-wastes management by King Oyster Mushroom cultivation. Considering the present scenario of *P.eryngii* cultivation, an advance technology for successful commercial cultivation of King Oyster Mushroom is needed for achieving the higher productivity with market acceptability.

**Keywords:** *Pleurotus eryngii*, King Oyster Mushroom, Agro-wastes, Supplements, Biological Efficiency.

### INTRODUCTION

The food security is an emerging issue worldwide due to increase of population to 7.5 billion people with an annual growth rate of 1.07% and shrinking of agricultural land. Nowadays, to fulfil the demand of nutritionally rich food, mushroom cultivation has been considered as one of the most efficient and economically viable biotechnology process to convert agro and industrial wastes into protein product. In Asian countries, easy availability of agricultural wastes, cheap labour and diversity of agro-climatic conditions make the

cultivation process more feasible. On an average, India produced 500 million tons of agro-wastes per year, out of which, 329 million tons used for fodder, fuel and industry purpose, 92 million tons burnt by farmers and 141 million tons were left as surplus agro-wastes (6). The FAO (2015) suggested that recent advancements in agriculture processes provide a route to combat food security through the sustainable utilization of surplus agro-waste which are rich in lignin and cellulose that will be suitable substrate for mushroom cultivation.

*Pleurotus eryngii* is known as King oyster mushroom and belongs to Class: Basidiomycetes and family: Agaricaceae and grown naturally in temperate and tropical forests absorbing nutrition from the decaying organic matter. The King oyster is cultivated under controlled environments in different parts of the world. *Pleurotus eryngii* has repository of enzymes such as laccases, Mn-oxidizing enzymes, acryl oxidase and cellulases that can degrade various lignocellulosic wastes such as straw of wheat, paddy, mustard, soybean, wood chips and sawdust, maize comb and cotton, millets, olive oil mill wastes (8, 27).

## **CULTIVATION OF *PLEUROTUS ERYNGII* ON DIFFERENT AGRO-WASTES**

FAO (2015) emphasized that sustainability of agricultural practises may provide the answer to rising problems through the use of agricultural wastes by growing mushrooms. Agro-wastes are generally generated at the rate of 1.5 times of the crop produced yearly which are rich in lignin and cellulose, that can be suitable substrate for King Oyster mushroom cultivation. King oyster mushroom has tremendous potential for the agricultural sector via bio-transforming residues into nutrients and functional food with various health-benefits. Globally, scientists of different countries have used several crop residues as substrates for cultivating the King oyster mushroom (5, 8, 16, 20, 27; Table - 1). Analyses of research work carried out during last two decades revealed that sawdust/wood chips are preferred substrates for King oyster mushroom cultivation internationally. Wheat straw, cotton seed/stalk and paddy/rice straw are other substrates used to grow King oysters but these substrates could not beat sawdust productivity as substrate. Moonmoon (2010) reported that King oyster mushroom yield and biological efficiency decreased under cultivation on sawdust + Rice stalk + 31% Ca.

However, the combination of barley straw + sugarcane-beet pulp substrate supplemented with wheat and rice bran and soybean powder was found as the best for King Oyster cultivation.

In India, *P.eryngii* mushroom is being cultivated on different substrates at 15–21°C temperature and 85–95% humidity in short day conditions but this protocol could not be made popular among farmers for its production at commercial scale. Hence, the contribution of this speciality mushroom is less than 1% of total production of 1.5 lakh tons of all kind mushroom at national level (8). Other than temperature and humidity, King oyster survival and multiplication are also influenced by environmental factors such as CO<sub>2</sub> concentration, fresh air and light which may act individually or synergistically in their regulating function during mushroom cultivation (17, 22).

## **ROLE OF SUPPLEMENTS ON PRODUCTIVITY**

The substrate supplementation plays an important role to influence the quality, size and shelf life of *P.eryngii* mushroom. The supplements are of following two types:–

### **Organic supplements**

wheat bran, rice bran, soybean powder, oil seed/cakes, cotton hulls etc.

### **Elements**

gypsum, CaO, Mn and Cu salts. The rice bran supplemented up to 20% of total substrate increased C/N ratio and final productivity of mushroom with nutritional value (23). Moreover, N, P, Mg, Fe, Zn, B and Ca content in King oyster mushroom fruiting body were reported for quality, size and shelf life of mushroom. The rice bran supplement with substrate is more popular than other supplements (27).

**Table 1: Substrates and Supplements used for King Oyster Cultivation**

| Substrate                                                                              | Supplements                                                                              | Country         |
|----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|-----------------|
| Wood chips Cotton seed hulls White millet                                              | Brewer's grain<br>Spawnmate IISE<br>Wheat bran $\text{CaCO}_3$                           | USA             |
| Sawdust                                                                                | Rice bran                                                                                | Taiwan          |
| <i>Quercus</i> sawdust                                                                 | Rice bran, Wheat bran, Acorn waste                                                       | Korea (19)      |
| Sawdust<br>Corn cob<br>Beet pulp                                                       | Rice bran, Wheat bran, Cotton seed cake, Corn bran, Zeolite, Shell lime, Bean curd dregs | Korea (24)      |
| Umbrella plant ( <i>Cyperus alternifolius</i> )<br><i>Cryptomeria japonica</i> sawdust | Wheat bran                                                                               | Japan (30)      |
| Alpeorujo<br>Olive press cakes<br>Wheat straw                                          | Wheat bran                                                                               | Greece          |
| Wheat straw<br>Millet straw<br>Cotton staw                                             | Rice bran                                                                                | Turkey (2)      |
| Sugarcane bagasse                                                                      | Rice bran, $\text{Ca(OH)}_2$                                                             | Japan           |
| Pine sawdust<br>Ginko leaf pomace                                                      | Wheat bran                                                                               | Korea (21)      |
| Sawdust<br>Rice straw                                                                  | Wheat bran, Rice husk, $\text{CaCO}_3$                                                   | Bangladesh (27) |
| Sawdust, Soybean straw, Sugarcane bagasse, Rice straw                                  | Wheat bran<br>$\text{CaCO}_3$                                                            | Egypt (12)      |
| Wheat straw, Cotton stalk                                                              | Rice bran                                                                                | Turkey (1)      |
| Sawdust                                                                                | Oyster shell powder                                                                      | Korea (7)       |
| Wheat straw<br><b>Casing:</b> spent compost, farm yard manure, and sandy soil.         |                                                                                          | India (26)      |
| Sawdust, Cotton seed hulls, Burma reed ( <i>Neyraudia reynaudiana</i> )                | Corn flour, Soy meal, Wheat bran, $\text{CaCO}_3$<br>$\text{CaSO}_4$                     | China           |

|                                                                                      |                                                                                                                |               |
|--------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|---------------|
| Wheat straw, Wood chips, Sawdust, Sugar beet pulp, Barley straw, Maize stem residues | Wheat bran<br>Rice bran<br>Soybean powder                                                                      | Iran (16)     |
| Beech sawdust<br>Wheat straw                                                         | Wheat bran, Pumpkin seed shells, Rice breach, Corn breach, Plaster                                             | Romania (4)   |
| Wheat straw                                                                          | Sugar beet pulp                                                                                                | Italy         |
| Sawdust<br>Wax apple branches<br>Indian jujube branches                              | Rice bran<br>Wheat bran<br>$\text{CaCO}_3$                                                                     | Taiwan (13)   |
| Ramie stalks, Kenaf stalks, Cotton seed hulls, Bulrush stalks                        | $\text{CaCO}_3$                                                                                                | China (41)    |
| Cotton waste<br>Fenugreek straw                                                      | Lime                                                                                                           | Pakistan (14) |
| Cotton waste                                                                         | Citrus peel<br>Lime                                                                                            | Pakistan (15) |
| Sawdust<br>Sugarcane bagasse                                                         | Korshinsk peashrub, Cottonseed hull, Ground corncobs, Wheat bran, Soybean meal, $\text{CaO}$ , $\text{CaSO}_4$ | China         |
| <i>Trigolium repens</i><br>Paper waste                                               | Lime<br>Gypsum                                                                                                 | Turkey (23)   |
| Sawdust                                                                              | <i>Thymus vulgaris</i> post extraction waste<br>Spent coffee ground                                            | Poland (11)   |
| Date palm waste<br>Corn cobs<br>Common reed                                          | Rice husk, Corn husk, $\text{CaCO}_3$                                                                          | Iraq (3)      |
| Wheat straw, Paddy straw, Maize straw, Sorghum straw                                 | Rice bran<br>Wheat bran                                                                                        | India (8)     |
| Wheat straw<br>cardboard                                                             | Spent coffee ground                                                                                            | Vietnam (29)  |
| Wheat straw, Beech wood shavings, Coffee residue, Barley straw, Oat straw, Rice bark | Wheat bran                                                                                                     | Greece (25)   |
| Cotton waste                                                                         | Moringa leaf powder                                                                                            | Pakistan      |

## YIELD AND BIOLOGICAL EFFICIENCY PATTERN

King oyster mushroom is the best among all the *Pleurotus* species due to its appealing consistency of pileus and stalk, culinary qualities and much longer shelf life than any other oyster mushrooms. Globally, many strains of *P. eryngii* are available and are extensively cultivated and respond differently to different substrates, supplements and environmental parameters in the aspects of mycelium run days, biological efficiency and quality of fresh mushroom. Upadhyay and Vijay (1991) reported the highest yield and biological efficiency of 73% on wheat straw supplemented with 20% dried brewer's grain while mushroom did not grow on unsupplemented wheat straw. Hassan et al. (2010) demonstrated 65% biological efficiency of *P. eryngii* on sawdust substrate. The higher mushroom productivity and biological efficiency has been reported on sawdust and its combination with other agro-wastes. Sawdust increased the productivity because of its lignin cellulosic content and other factors like porosity, carbon, nitrogen, moisture and pH. The data also revealed that biological efficiency varied in different substrates and combination due to their cellulosic, hemicellulosic and lignin contents, quality of substrates and spawn, diversity in cultivated strains of *P. eryngii* and interaction between substrates and supplements (5, 12,). Peng et al. (2000) compared the average yield, biological efficiency and production efficiency of *P. eryngii* strains – ATCC 36047 and Holland-150 and found that significant increase in biological efficiency of *P. eryngii* -36047 was achieved with increase supplementation of substrate with rice bran (0.0-47.95%). While the Holland-150 strain showed the highest BE (38.08%) with rice bran but decreased significantly when rice bran supplementation was increased to 47.95%.

## CONCLUSION

It can be concluded that there is a great

scope for the sustainable disposal of agro-wastes by King oyster mushroom cultivation. Conventional practices for cultivation of King oyster mushroom on different agro-waste substrates are not meeting the need of country as plenty of agro-wastes are still left unutilized. Therefore, suitable advance technologies for successful cultivation of different *P. eryngii* strains are needed to be standardized for achieving high yields and biological efficiency. Proper technology with integrated approach may be transferred to the farmers to uplift their economic status. High yielding strains of *P. eryngii* along with long shelf life are essential for the successful commercial cultivation. Research should also be focussed on breeding and development of new high yielding strains. The mushroom cultivation technology is based on zero energy concept and the waste or spent substrate left after harvest, may be used as organic fertilizer for harnessing the good yield of conventional crops. It will reduce the financial burden of farmers and will save the environment from the harmful effect of chemical fertilizers on another hand.

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## EFFECT OF PRE-SOAKING CHEMICAL TREATMENTS ON SEED GERMINATION AND SEEDLING VIGOUR OF PAPAYA (*CARICA PAPAYA* L.) C.V. RED LADY UNDER NET HOUSE CONDITION

Hemant Kumar Panigrahi\* and Sangeeta

Dept. of Fruit Science, College of Agriculture Indira Gandhi  
Krishi Viswa-Vidyalaya, Krishak Nagar, Raipur (C.G.)

\*Corresponding Author E-mail– [sanjuchandu1995@gmail.com](mailto:sanjuchandu1995@gmail.com)

### ABSTRACT

An experiment was conducted to study the effect of pre-soaking chemical treatments on seed germination and seedling vigour of papaya (*Carica papaya* L.) cv. Red Lady under net house at Research Farm of Centre of Excellence on Protected Cultivation and Precision Farming, College of Agriculture, IGKV, Raipur during the year 2019-2020. The experiment was laid out in a Completely Randomized Design having nine treatments replicated three times. The treatment comprises different concentrations of Gibberellic Acid ( $GA_3$ ), Potassium Nitrate, Benzyl Adenine, Thiourea and water (control). Result of experiment revealed that pre-soaking of papaya seeds with  $T_2(GA_3 @ 200 \text{ ppm})$  had significant effect on seed germination and took minimum number of days for germination (15.13 days). Rate of seedling emergence (80.66%), germination percentage (82.32%), germination index (2.29), root: shoot ratio on dry weight basis (0.26) and seedling vigour index-II (202.23) were also recorded maximum under the same treatment. Seedling vigour index-I (1425.40) was significantly influenced and recorded maximum under the treatment  $T_7$  (Thiourea @ 1000 ppm) as compared to rest of the treatment under the present trial.

**Keywords:** Papaya, Gibberellic Acid ( $GA_3$ ), Potassium Nitrate, Benzyl Adenine, Thiourea, seed germination, seedling vigour etc.

### INTRODUCTION

Papaya (*Carica papaya* L.) is an important tropical fruit crop, belongs to the family Caricaceae. It gives one of the highest productions of fruits per hectare and an income next to banana as well as it is cheaper source of vitamin A and minerals. Nutritionally, papaya is a good source of vitamin A (2020 IU/100 g), vitamin C (85 mg/100 g) carbohydrates (7.2%) and minerals (0.4%), proteins (0.5%), fat (0.1%), calorific

value (4.0%) and vitamin B (250 IU/100 g).

In India, papaya is grown widely occupying an area approximately 138 thousand hectares with an annual production of 5989 thousand metric tonnes of fruits with a productivity of 39.96 mt/ha (4). In Chhattisgarh, papaya is 2 cultivated in an area around 13.72 thousand hectares with the production of 341.93 thousand metric tonnes (3).

Papaya is generally propagated by seed. Proper seed germination and seedling growth

are most important considerations in successful sapling production under nursery technique of papaya cultivation. A wide variety of pre-sowing seed treatment, which includes the plant growth regulators and growing media are used to enhance the seed germination and seedling growth in several fruit crops. Seed viability declines as the gelatinous sarcotesta persists unchanged with a more prominent impact in dried seeds than in fresh ones. Seed dormancy and germination are complex adaptive traits of higher plants that are influenced by a large number of genes and environmental factors. The significant role of chemical treatments through  $GA_3$ ,  $KNO_3$ , sodium thiosulphate and thiourea in relation to breaking dormancy, seed germination, growth and development of plant (10).

Red Lady is an important and dominant cultivar of papaya, which is performing very well in the climate of Chhattisgarh. In view of the above facts, the present investigation was carried out to study the effect of pre-soaking chemical treatments on seed germination and seedling vigour of papaya (*Carica papaya* L.) cv. Red Lady under net house condition.

## MATERIALS AND METHODS

The Experiment was conducted at Research Farm of Centre of Excellence on Protected Cultivation and Precision Farming under net house, College of Agriculture, IGKV, Raipur during the year 2019-2020. The experiment was laid out in a completely randomized design. There were nine treatments viz.  $T_0$  = Control (water),  $T_1$  = Gibberellic Acid @100 ppm,  $T_2$  = Gibberellic Acid @200 ppm,  $T_3$  = Potassium Nitrate @0.5%,  $T_4$  = Potassium Nitrate @1%,  $T_5$  = Benzyladenine @50 ppm,  $T_6$  = Benzyladenine @100 ppm,  $T_7$  = Thiourea @1000 ppm and  $T_8$  = Thiourea @2000 ppm replicated thrice. The treated seeds were grown in poly bag filled with growing media of Soil: Sand:FYM in the

ratio of 2:1:1. In control water-soaked seeds were sown in polythene bags. All cultural practices and plant protection measures were applied uniformly to all treatments during entire experimental period as required. The stock solution different chemicals were prepared and then diluted according to the need. Papaya seeds are treated with the pre-soaked chemicals.

The observations recorded on seed germination and seedling vigour are days taken to start germination, rate of emergence (%), germination percentage (%), germination index (%), root: shoot ratio, seedling vigour index-I, seedling vigour index-II. The observation on various characters were recorded and subjected to statistical analysis to test the level of significance as per method by (8).

## RESULTS AND DISCUSSION

### Seed Germination Parameters

The seed germination characteristics were recorded for the following variables namely days taken to start germination, rate of emergence (%), germination (%) and germination index (%) are presented in Table 1.

### Days taken to germination

The days taken to germination of papaya seed was significantly influenced by various pre-soaking treatments under the present investigation. The minimum days required for germination (15.13) was recorded under the treatment  $T_2$  ( $GA_3$  @ 200 ppm). However, the maximum number of days required for seed germination (22.43 days) was observed under the treatment control ( $T_1$ ). The decrease in number of days required for germination is might be due to the fact that  $GA_3$  plays an important role in two stages of germination one at initial enzyme induction and other in activation of reverse food mobilizing system which help in enhancement of germination (9).

The above results are conformity with the results of (6, 1) and (5) in papaya.

### Rate of Emergence (%)

The maximum rate of emergence of papaya seed (80.66%) was registered under the seeds treated with GA<sub>3</sub> @ 200 ppm (T<sub>2</sub>), which was found significant differences among all other treatments. The minimum rate of emergence (59.10%) was observed under control treatment (T<sub>0</sub>). The increase in the rate of emergence of papaya is might be due to the fact GA<sub>3</sub> having stimulatory effect in the formation of enzymes, which are important in early phase of germination. (7) also reported higher rate of germination of papaya seeds treated with GA<sub>3</sub>. These results were in close agreement with the findings of (5) and (2) in papaya.

### Germination (%)

The maximum germination percentage of papaya seed (82.32%) was recorded under the treatment T<sub>2</sub> (GA<sub>3</sub> @ 200 ppm), which was found significantly superior from rest of the treatments under 5% level of significance. The minimum germination percentage (56.47%) was registered under the treatment T<sub>0</sub> (control). The increase in germination percentage of papaya is might be due to the fact that GA<sub>3</sub> participates in the activity of alpha-amylase, which catalyzes the starch conversion into simple carbohydrates and chemical energy is liberated which is used in the activation of embryo. This result is in close conformity with the findings of (2) in papaya.

### Germination Index

The maximum germination index of papaya seeds (2.29) was recorded under the treatment GA<sub>3</sub> @ 200 ppm (T<sub>2</sub>), which was showed significant differences among all other treatments. The minimum germination index (1.51) was registered under the control (T<sub>0</sub>). The increase in

germination index of papaya seeds is might be due to the fact that GA<sub>3</sub> which influenced in early germination and increased per cent germination. The results are in close conformity with the findings of (13) in aonla.

### Seedling characteristics

The seedling characteristics were recorded for the following variables i.e., root shoot ratio on dry weight basis, seedling vigour index-I and seedling vigour index-II. They are presented in Table 2.

#### Root: shoot ratio on dry weight (g)

The maximum root shoot ratio on dry weight basis (0.26) was recorded under the treatment GA<sub>3</sub> @ 200 ppm (T<sub>2</sub>) followed by T<sub>8</sub> having the root shoot ratio on dry weight (0.15). The minimum root shoot ratio on dry weight (0.13 g) was registered under control. It is evident from the result obtained under the present investigation that the application different pre-soaking chemicals had significantly influenced the root: shoot on dry weight as compared to control. It might be due to the higher dry weight of roots and shoots of papaya plant. The Endogenous gibberellic acid synthesized by the seed embryo not be sufficient and as such the external application might have boosted the growth by increasing cell multiplication and cell elongation, resulting in rapid plant growth and development. The present results are in conformity with the finding of (11) in jackfruit and (16) in papaya.

#### Seedling vigour index-I

The maximum seedling vigour index-I (1425.4) was recorded under the superiority of treatment T<sub>7</sub> (Thiourea @1000 ppm), which showed significant differences among all other treatments under present investigation. The minimum seedling vigour index-I (472.33) was observed under control. The increase in seedling vigour index-I of papaya plant is might be due to thiourea increases germination percentage and seedling length. The seed treated with thiourea has highest per cent of germination and recorded the highest plant height. These results

are in conformity with the findings reported by (15, 12, 1, 7) and (6) in papaya.

## Seedling vigour index-II

The maximum seedling vigour index-II (202.23) was noticed under the treatment T<sub>2</sub> (GA<sub>3</sub> @ 200 ppm), which was showed significantly superior among all other treatments. The minimum seedling vigour index-II (33.69) was registered under T<sub>0</sub> (control). The increase in seedling vigour index-II of papaya plant is might be due to more seedling dry weight due to effect gibberellic acid treatment. The present result is in close agreement with the result obtained by (14) in kagzi lime.

**Table 1. Seed germination parameters of papaya (*Carica papaya L.*) cv. Red Lady as influenced by pre-soaking chemical treatments of seeds under net house condition**

| Notations      | Treatments                 | Days taken to germination | Rate of emergence (%) | Germination (%) | Germination index |
|----------------|----------------------------|---------------------------|-----------------------|-----------------|-------------------|
| T <sub>0</sub> | Control (water)            | 22.43f                    | 59.10a                | 56.47a          | 1.51a             |
| T <sub>1</sub> | Gibberellic Acid @ 100 ppm | 17.14b                    | 79.75g                | 80.78g          | 2.04e             |
| T <sub>2</sub> | Gibberellic Acid @ 200 ppm | 15.13a                    | 80.66h                | 82.32h          | 2.29f             |
| T <sub>3</sub> | Potassium Nitrate @ 0.5 %  | 17.60c                    | 72.02b                | 75.23c          | 1.72b             |
| T <sub>4</sub> | Potassium Nitrate @ 1%     | 20.37e                    | 73.14c                | 78.81f          | 1.71b             |
| T <sub>5</sub> | Benzyladenine @ 50 ppm     | 17.17bc                   | 72.25b                | 78.67e          | 1.82c             |
| T <sub>6</sub> | Benzyladenine @ 100 ppm    | 20.11e                    | 77.03d                | 78.71ef         | 1.87d             |
| T <sub>7</sub> | Thiourea @ 1000 ppm        | 20.27e                    | 78.68e                | 77.14d          | 2.03e             |
| T <sub>8</sub> | Thiourea @ 2000 ppm        | 18.08d                    | 79.57f                | 73.56b          | 1.80c             |
| SE(m)±         | 0.15                       | 0.19                      | 0.19                  | 0.009           |                   |
| CD at 0%       | 0.45                       | 0.57                      | 0.59                  | 0.027           |                   |

\*The superscript letter indicates that the treatment means with same letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD- value comparison of treatment means.

**Table 2. Seedling characteristics of papaya (*Carica papaya L.*) cv. Red Lady as influenced by pre-soaking chemical treatments of seeds under net house condition**

| Notations      | Treatments                 | Root:shoot ratio on dry weight basis (g) | Seedling vigour index-I | Seedling vigour index-II |
|----------------|----------------------------|------------------------------------------|-------------------------|--------------------------|
| T <sub>0</sub> | Control (water)            | 0.13a                                    | 472.33a                 | 33.69a                   |
| T <sub>1</sub> | Gibberellic Acid @ 100 ppm | 0.21e                                    | 1,007.41b               | 109.60c                  |
| T <sub>2</sub> | Gibberellic Acid @ 200 ppm | 0.26f                                    | 1,287.24f               | 202.23h                  |
| T <sub>3</sub> | Potassium Nitrate @ 0.5 %  | 0.19d                                    | 1,092.13c               | 118.61d                  |
| T <sub>4</sub> | Potassium Nitrate @ 1%     | 0.18cd                                   | 1,307.51f               | 129.25f                  |
| T <sub>5</sub> | Benzyladenine @ 50 ppm     | 0.18cd                                   | 1,150.16d               | 151.04g                  |
| T <sub>6</sub> | Benzyladenine @ 100 ppm    | 0.22e                                    | 1,220.64e               | 122.27e                  |
| T <sub>7</sub> | Thiourea @ 1000 ppm        | 0.17c                                    | 1,425.40g               | 107.23c                  |
| T <sub>8</sub> | Thiourea @ 2000 ppm        | 0.15b                                    | 1,028.12b               | 89.74b                   |
| SE(m)±         | 0.005                      | 16.38                                    | 1.09                    |                          |
| CD at 5%       | 0.015                      | 49.06                                    | 3.27                    |                          |

\*The superscript letter indicates that the treatment means with same letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD- value comparison of treatment means.

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# EVALUATION OF THE IN VITRO EFFICACY OF *CAPPARIS SPINOSA* L. ALCOHOLIC EXTRACT IN CONTROLLING THE HAIRY GRAIN BEETLE (KHABRA) *TRAGODERMA GRANARIUM* EVERTS (COLEOPTERA; DERMESTIDAE)

Farah Hadi Abdul Hussain\* and Yousef Dakhil Rashid

Al-Mussaib Technical College, Al-Furat Al-Awasi Technical University, Babylon, Iraq

\*Corresponding Author E-mail– [hassan.alkarawi@atu.edu.ig](mailto:hassan.alkarawi@atu.edu.ig)

## ABSTRACT

This research was carried out to investigate the effects of the alcoholic extract of the leaves and roots of *C. spinosa*, at concentrations of 10, 20, and 30 mg/ml on the larvae of the second and fourth instars of the hairy grain beetle (Khabra) *T. granarium*. The results showed the superiority of the alcoholic extract of the leaves at the concentration of 30 mg/ml in killing the second and fourth larval instars, with mortality rates of 48.3 and 60.0%, respectively. As for the alcoholic extract of the roots, the concentration of 30 mg/ml caused the highest mortality rate in the second and fourth larval instars, with mortality rates of 23.3 and 28.3 %, respectively.

**Keywords:** Hairy grain beetle *Tragoderma ganarium*, *Capparis spinosa*

## INTRODUCTION

Cereals and their products are exposed to various damages in the field and storage facilities as a result of being infected with many different pests. The incidence of infection with these pests is estimated at 30-25% of the world's annual production of field crops, whether inside the field or at storage (2). Stored grains are the most important source of human food, since they are the main source for proteins, carbohydrates and other basic nutrients that humans need. Wheat occupies the first rank among these grains in terms of nutritional value, constituting the main food for more than 35% of the world's population, in addition to containing important proteins such as gluten, which is used in many major food

industries (12). One of the most serious difficulties facing the process of maintaining the quality of grains and their products during storage is the storehouse insects. The most important store pests that attack these grains is the hairy grain beetle (Khabra) *T. ganarium* Everts, which is one of the most dangerous and pesticide-resistant insects (13). These beetles have adapted to develop and grow in dry environments, especially in grain stores, where they consume large quantities of grains and pollute them with their secretions, thus affecting their marketing value (7). All these problems prompted the farmers to use pesticides as the fastest means to eliminate the pests. However, the misuse of pesticides, both in terms of high concentration and frequency, causes the contamination and

accumulation of their residues in human food and the environment. The development of resistance to pesticides by these insects is an additional problem (5). In order to avoid the emergence of such problems, various plant extracts that act as safe pesticides have been applied (14). *Capparis spinosa* contains effective natural products against pests, and many researchers attributed this effectiveness to the high contents of glycosides, phenols and alkaloids (15). The present investigation has the aim of testing the influences of the alcoholic extract of leaves and roots of *C. spinosa* on some aspects of life performance of *T. granarium* in vitro.

## MATERIALS AND METHODS

### Collection and breeding of *T. granarium*

The hairy grain beetle (Khabra) *T. granarium* was obtained from the laboratories of the Ministry of Science and Technology. Healthy grains of wheat were cleaned of impurities and placed in the freezer for 72 hours at -20 Celsius to ensure that they are internally free from infection with any other insect. Ten adult pairs of males and female beetles were placed on 1 kg of healthy wheat grains, with 5 g of dry yeast in 100 ml plastic bottles with a diameter of 10 cm. The opening of the bottle was covered with a piece of muslin fabric and sealed with a rubber band to prevent the escape of the adults. The replenishment of the culture was ensured from time to time (6). The insect species was identified by an expert in the Natural History Research Center and Museum, University of Baghdad.

### Collection of plant samples

*C. spinosa* samples were collected from orchards in Babylon Governorate on 24/4/2021 and then identified by an expert at the

Natural History Research Center and Museum, University of Baghdad. The leaves and roots were isolated and washed separately for the purpose of removing dust, dried at room temperature with constant stirring to prevent rotting, ground with an electric grinder, and kept in clean, dry bags in the refrigerator until use.

### Preparation of alcoholic extract of *C. spinosa*

#### Preparation of leaf extract

The method of Harborn, 1998, was adopted in preparing the alcoholic extracts. Ten grams of dry powder of leaves was placed in a Soxhlet apparatus, to which 200 ml of ethyl alcohol was added. The extraction process lasted for 24 hours at a temperature of 45 °C. The extracted material was concentrated by using a rotary evaporator and the process was repeated several times to obtain a sufficient amount. After that, the sample was dried in an electric oven at a temperature of 40 - 45°C. The dry sample was placed in airtight glass containers with known weights and kept in the refrigerator until use. For the purpose of testing the effect of the crude leaf alcoholic extract, 8 g of the dry matter of the leaves was dissolved in 5 ml of 99% ethyl alcohol and 3 ml of the Tween 20. The volume was brought up to 100 ml with distilled water, yielding a stock solution of 8 % concentration, or equivalent to 80 mg / ml, from which the concentrations of 10, 20, and 30 mg / ml were prepared. The control treatment consisted of 5 ml of ethyl alcohol, where the volume was completed to 100 ml with distilled water.

#### Preparation of root extract

The alcoholic extract of the roots of *C. spinosa* was prepared by following the same method described above for the leaves.

## Laboratory experiment

### Effects of alcoholic extract of *C. spinosa* on the mortality rate of the second and fourth larval instars of *T. granarium*

Twenty larvae from the second and fourth instars were used to study the effects of the three concentrations of the extract tested, in addition to the control treatment. For each treatment, 5 larvae were placed in a petri dish and sprayed with the leaf alcoholic extract at concentrations of (10, 20, and 30 mg/ml) by utilizing a hand sprayer. To ensure complete coverage, the spraying was conducted from a distance of 5 cm. After spraying, food was provided for the larvae, which is a mixture of previously-prepared wheat powder and yeast. The dishes were incubated at a temperature of  $30 \pm 2^\circ\text{C}$ . The control treatment comprised 5 ml of ethyl alcohol which was completed to 100 ml with distilled water. The mortality rate was calculated after periods of 1, 3, 5, and 7 days.

### Effects of the alcoholic extract of *C. spinosa* roots on the mortality rate of the second and fourth larval instars of *T. granarium*

Larvae of the second and fourth instars of the hairy beetle were treated with the root

alcoholic extract by following the same procedure described above for the alcoholic extract of the leaves.

## Statistical analysis

The laboratory experiment was carried out according to the Complete Randomized Design (C.R.D), based on the factorial experiments. The Least Significant Difference (LSD) test was used under the probability level of 0.05 to test the significance of the differences. The mortality rate was corrected according to Abbott's equation (1).

## RESULTS AND DISCUSSION

Table 1 indicates the impacts of the interaction between the concentrations of the leaf and root alcoholic extracts of *C. spinosa* with the time period on the killing of the second larval instar of the hairy beetle (Khabra). The superiority of the alcoholic extract of the leaves at the concentration of 30 mg/ml was evident, causing the highest mortality rate of 60.0%. The lowest mortality rate was 15.6%, which was recorded in response to the treatment with 10 mg/ml of the root alcoholic extract.

**Table 1. Effects of the alcoholic extract concentrations of *C. spinosa* leaves and roots on the mortality rate of the second larval instar of *T. granarium*.**

| Extract type                              | Time (hr) Conc. (mg/ml) | 1    | 3    | 5    | 7    | Mean for the concentration |
|-------------------------------------------|-------------------------|------|------|------|------|----------------------------|
| Leaf extract                              | 0                       | 0.0  | 0.0  | 0.0  | 6.7  | 1.7                        |
|                                           | 10                      | 13.3 | 26.7 | 40.0 | 66.7 | 36.7                       |
|                                           | 20                      | 20.0 | 33.3 | 53.3 | 86.7 | 48.3                       |
|                                           | 30                      | 26.7 | 40.0 | 73.3 | 100  | 60.0                       |
| Root extract                              | 10                      | 0.0  | 13.3 | 20.0 | 25.0 | 15.6                       |
|                                           | 20                      | 6.7  | 20.0 | 26.7 | 33.3 | 21.7                       |
|                                           | 30                      | 13.3 | 26.7 | 33.3 | 40.0 | 28.3                       |
| Mean for time                             |                         | 11.4 | 23.0 | 35.2 | 51.2 |                            |
| L.S.D value (0.05) for the concentrations |                         |      |      |      |      | 3.12                       |

It was also noticed that the longer the time period of treatment with the alcoholic extract, the higher the mortality rate, as reflected by rates of 11.4, 23.0, 35.2, and 51.2 % after 1, 3, 5, and 7 days, respectively.

Moreover, it was observed that the higher the concentration, the higher the death rate; the rates reached values of 48.3, 36.7, 60.0 % in response to treatment with the concentrations of 10, 20, and 30 mg / ml of the leaf alcoholic extract, respectively, whereas they were 15.6, 21.7, and 28.3 in response to the same concentrations of the root extract. As for the interaction between concentrations and time periods, the highest mortality rate (100%) was recorded for the leaf extract at the concentration of 30 mg/ml on the seventh day, with highly significant differences from the remainder of the treatments, whereas the control treatment showed a mortality rate of 6.7% on the seventh day. The results of the statistical analysis indicated significant differences among the obtained results.

### Effects of the concentrations of the leaf and root alcoholic extracts of *C. spinosa* on the mortality rate of the fourth larval stage of *T. granarium*.

Table 2 indicates the effects of the interaction between the alcoholic extract concentrations of *C. spinosa* leaves and roots and the treatment period on the mortality of the fourth larval stage of the hairy beetle. The superiority of the alcoholic leaf extract at a concentration of 30 mg/ml was reflected by the highest rate of mortality rate (48.3%), whereas the lowest (10.0%) was recorded with the root extract at the concentration of 10 mg / ml. It is also noted that the longer the time period of treatment, the higher the mortality rate, which reached values of 8.6, 17.1, 27.6, and 42.9 % after 1, 3, 5, and 7 days, respectively. It is also noted observed that the higher the concentration, the higher the mortality rate. The values reached 30, 40.0, and 48.3% following treatment with the leaf alcoholic extract at concentrations of 10, 20, and 30 mg/ml, respectively.

**Table 2: Effects of the concentrations of the leaf and root alcoholic extracts of *C. spinosa* on the mortality rate of the fourth larval stage of *T. granarium*.**

| Extract type                                        | Period (day)<br>Conc. (mg/ml) | 1    | 3    | 5    | 7    | Mean for<br>concentration |
|-----------------------------------------------------|-------------------------------|------|------|------|------|---------------------------|
| Leaf extract                                        | 0                             | 0.0  | 0.0  | 0.0  | 0.0  | 0.0                       |
|                                                     | 10                            | 6.7  | 20.0 | 33.3 | 60.0 | 30.0                      |
|                                                     | 20                            | 13.3 | 26.7 | 46.7 | 73.3 | 40.0                      |
|                                                     | 30                            | 20.0 | 33.3 | 53.3 | 86.7 | 48.3                      |
| Leaf extract                                        | 10                            | 0.0  | 6.7  | 13.3 | 20.0 | 10.0                      |
|                                                     | 20                            | 6.7  | 13.3 | 20.0 | 26.7 | 16.7                      |
|                                                     | 30                            | 13.3 | 20.0 | 26.7 | 33.3 | 23.3                      |
| Mean for time                                       |                               | 8.6  | 17.1 | 27.6 |      | 42.9                      |
| L.S.D (0.05) for the concentrations                 |                               |      |      |      |      | 2.43                      |
| L.S.D (0.05) for the time                           |                               |      |      |      |      | 2.85                      |
| L.S.D (0.05) for the concentration/time interaction |                               |      |      |      |      | 5.11                      |

As for the root alcoholic extract, the values reached 10.0, 16.7, and 23.3% at concentrations of 10, 20, and 30 mg/ml, respectively. The interaction between

concentrations and time periods demonstrated that the highest mortality rate was for the leaf extract at the concentration of 30 mg/ml, reaching 86.7% on the seventh day. These

values had highly significant differences in comparison with the other treatments, whereas the control group did not exert mortality. The results of the statistical analysis indicated significant differences in the obtained results.

The death of the larvae is due to the influences of the toxic substances present in the extracts on the nervous system. These extracts activate the enzyme acetylcholinesterase, leading to the secretion of acetylcholine, which is important in transmitting the impulses that accumulate at the nerve endings, and eventually cause paralysis and death (10, 14). The alcoholic extract of the leaves and roots exerted the highest rate of mortality in the second larval stage, reaching 100%, whereas the lowest rate was recorded in the fourth larval stage, reaching 20.0%. The reason behind this influence is the nature of the body of the initial larval instars, which possess less thickness of the cuticle layer than that in the advanced instars. The results showed a significant difference between the two larval instars, where the highest mortality rate in the second larval instar was 100%, whereas that in the fourth instar was 20.0 %. The reason can possibly be the different sensitivity of the larval stages due to the differences in the development level of the detoxification mechanisms in the early stages compared with the advanced stages of life (3, 8).

The study of (8), revealed that the extract of the crude terpene compounds of *C. spinosa* had influences on the death and growth period of the small grain borer *Rhizopertha dominica*, where the cumulative mortality rate of the non-mature stages increased was 100% as a result of the treatment with the two concentrations of 5 and 10 mg/ml from both the leaf and fruit extracts, whereas the control treatment caused a rate of 22.2%.

The results of the present investigation agree with those reported by Al-Timimi, 2021,

who tested the impacts of the crude extract of *C. spinosa* at concentrations of (50, 25, 12.5) mg/ml on the bird lice insect, where the mortality rate of nymphs reached 100%.

The results presented here are also consistent with those reported by Imran, 2021, who examined the influences of the alcoholic extract of *Moringa oleifera* on the insect *Oryzaephilus surinamensis*. The study showed mortality rates of 50, 73, and 80% for the fourth larval instar at concentrations of 1, 2, and 4%, respectively. The study also tested the effects of this alcoholic extract on the insect *Rhyzopertha dominica*, revealing mortality rates of 66, 80, and 100% for the second larval instar at concentrations of 1, 2, and 4%, respectively.

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## CRISPR/CAS9 TECHNOLOGY APPLICATIONS IN POTATO : A REVIEW

Subhash Kumar<sup>1</sup>, Shri Kant<sup>2\*</sup>, Sandeep Kumar<sup>3</sup>, Everest Shiwach<sup>4</sup>  
and Seema Rani<sup>5</sup>

<sup>1</sup>Department of Botany, C.C.R(PG) College, Muzaffarnagar (U.P.), India

<sup>2</sup>Department of Ag. Botany, C.C.R(PG) College, Muzaffarnagar (U.P.), India

<sup>3,5</sup>Department of Botany, Meerut College, Meerut (U.P.), India

<sup>4</sup>Department of Botany, D.N. College, Meerut (U.P.), India

\*Corresponding Author E-mail– [shrikant2704@rediffmail.com](mailto:shrikant2704@rediffmail.com), [subhashvikal2012@gmail.com](mailto:subhashvikal2012@gmail.com)

### ABSTRACT

Potato (*Solanum tuberosum* L.), a member of family Solanaceae is the third largest food crop in the world after wheat and rice. It is mainly used as a fresh food or raw material for food processing (e.g., Chips and French fries) and specific industries (e.g., starch and ethanol). In addition to high carbohydrate and low fat, the potato tuber has balanced nutritional value with vitamins and minerals, making this crop ideal for the human diet and important for food security. Potato has wide distribution and adaptability to various environmental and climatic conditions but it is sensitive to various environmental stresses like water stress (drought and flooding), extreme temperature (low and high), and ion toxicity (salinity and heavy metal) etc. The cultivated potato are vegetatively propagated and are predominantly autotetraploids ( $2n = 4x = 48$ ) i.e. diploid to hexaploid. In 2011, the first potato reference genome and transcriptome were published by the Potato Genome Sequencing Consortium (PGSC) using a whole-genome shotgun (WGS) approach. Earlier, conventional breeding, bi-parental linkage mapping, and Marker Assisted Selection (MAS) have been successfully demonstrated in potato. The potato genome sequencing and resequencing allow discovery of genes, markers and other regulatory elements to provide better understanding of the crop. There is an immense potential of genome editing for rapid breeding of climate resilient varieties resistant/tolerant to biotic and abiotic stresses. Nonetheless, the availability of an efficient CRISPR/Cas9 system, target gene selection, plant transformation, and off target mutants would be some challenges in tetraploid crop.

**Keywords:** CRISPR/Cas9 technology, Potato, Applications

### INTRODUCTION

Potato crop is very sensitive to biotic and abiotic stresses. Potatoes are susceptible to a wide variety of biotic stresses which reduces

both productivity and quality of the tubers.

### Biotic Stress in Potato

Among the insect pathogens, the Colorado potato beetle (*Leptinotarsa decemlineata* Say)

is very harmful due to its devastation and resistance to insecticides. Some insects feed on tubers, weakening the plant and leading to production losses. Furthermore, some insects can be problematic for their viral pathogen vector roles, notably the aphid-borne potato leaf roll virus (PLRV) and potato virus Y (PVY). (17,18,19) Potatoes are also affected by nematodes, and by several bacterial species such as *Ralstonia solanacearum*. Nevertheless, the pathogen that generates the most striking losses worldwide is the oomycete pathogen *Phytophthora infestans*, which causes Late Blight Disease of Potato leading to premature plant death. Additional fungal pathogens of concern include *Alternaria solani*, numerous species of *Fusarium* and *Rhizoctonia*; and *Passalora concors*, which causes a disease called Cercospora leaf blotch. (14,15,16)

### Abiotic Stress in Potato

Potato has wide distribution and adaptability to various environmental and climatic conditions but it is sensitive to various environmental (or Abiotic) stresses like Water stress (drought and flooding), extreme temperature (low and high), and ion toxicity (salinity and heavy metal) etc. Abiotic stresses also a major cause of reduction in yield and quality of potato. (1)

## BREEDING APPROACHES FOR BIOTIC AND ABIOTIC STRESS RESISTANT PLANTS

Several plant breeder develop biotic and abiotic stress resistant varieties to mitigate the effects of these stresses on production and quality of potato prior by traditional breeding methods like selection, mutation, hybridization etc. Later on conventional breeding, bi-parental linkage mapping, and Marker Assisted Selection (MAS) have been successfully demonstrated in potato. After that advanced biotechnological breeding methods like transgenics have also been applied. (10,11,12). In 1995, Monsanto

introduced the NewLeaf variety of potato which was their first genetically modified crop. It was designed to resist attack from the Colorado potato beetle due to the insertion of Bt toxin producing genes from the bacterium *Bacillus thuringiensis*.

Some commercialized Genetically Modified Crops are as follows

### 1. NewLeaf™

Colorado potato beetle resistance potato variety developed through Cry3A gene introduction in 1995 (US, CAN) (Monsanto®)

### 2. NewLeaf™

PlusColorado potato beetle and potato leaf roll virus resistance variety developed by introduction of Cry3A and PLRV replicase and helicase genes in 1998 (US) (Monsanto®)

### 3. NewLeaf™ Y

Colorado potato beetle and potato virus Y resistance variety developed by Cry3A and PVY coat protein introduction in 1998 (US) (Monsanto®)

### 4. Innate® 1.0

Reduced acrylamide formation and black spot bruise Asn1 and Ppo2 down-regulation, 2015 (US) (J.R. Simplot®)

### 5. Innate® 2.0

Reduced acrylamide formation, black spot bruise and CIS; *Phytophthora infestans* resistance Asn1, Ppo2 and Vlnv down-regulation; Rpi-vnt1 introduction, 2017 (US)

### 6. Amflora™

Reduced amylose formation GBSSI down-regulation, 2010 (EU)(BASF Plant Science)

### 7. Starch potato

Reduced amylose formation GBSSI down-regulation 2014 (EU)(BASF Plant Science)

### 8. Elizaveta Plus/ Lugovskoi Plus

Colorado potato beetle resistance Cry3A introduction, 2005/2007 (RU) (Russian Academy of Sciences)

## REGULATIONS FOR GENETICALLY MODIFIED (GM) CROPS IN INDIA

In India only Bt Cotton is approved for commercial cultivation and till now no transgenic food crop get approval commercial cultivation in India. Development, cultivation and transboundary movement of GM crops is regulated so as to ensure the safety of animal health, human health and biodiversity. In India, such regulations are provided in the Rules for Manufacture, Use, Import, Export and Storage of Hazardous Microorganisms (HM) Genetically Engineered Organisms or Cells, 1989 under the Environment Protection Act (1986). The rules cover:

- All activities involving research and development of products containing GMOs including transgenic crops, pharma products, industrial products, food and foodstuffs.
- Field and clinical trials
- Deliberate or unintentional release
- Import, export and manufacture

Transgenic potatoes developed for resistance to diseases (e.g., late blight and viruses), abiotic stresses (e.g., heat and drought), insect pest (e.g., potato cyst nematode and potato tuber moth), processing quality (e.g., reduced cold-induced sweetening), but none of them are being applied at the field level in India (9).

Genetic engineering initiated in 1983 with introduction of first exogenous DNA into a plant by transformation with *Agrobacterium tumefaciens*. *Agrobacterium*-mediated gene delivery was the first genetic modification system used in crops. RNA interference (RNAi) technology in plants emerged some years later with the demonstration that gene silencing was initiated by double-stranded RNA (dsRNA). These initial experiments used sense and antisense sequences to degrade Potato Virus Y (PVY) viral RNA. (8)

## GENOME EDITING, A NOVEL

## APPROACH FOR PLANT BREEDING

It is necessary to increase crop varieties to cope with abiotic stresses. Traditional selection or breeding methods, such as marker-assisted selection, are ways to produce crop varieties. ZFNs, TALENs, and CRISPR/Cas systems have been used for different purposes in modern agriculture, such as obtaining plants with tolerance to abiotic stresses, such as temperature, drought, and salinity stresses. With the emergence of CRISPR/Cas, these processes have become more rapid and accurate. In recent years, many advances have been made in genome-editing technologies, such as the modification of known structures or the discovery of new enzymes or methodologies. (7)

The next generation of genetic modification tools are based on sequence-specific nucleases (SSN), proteins with nuclease activity that generate sequence-specific double strand breaks (DSB). The use of SSNs in crops includes the Zinc Finger Nuclease (ZFN), the Transcription Activator-Like Effector Nuclease (TALEN) and the Clustered Regularly Interspaced Short Palindromic Repeats/CRISPR associated protein 9 (CRISPR/Cas9). The repair of DSBs produced by SSN can be carried out by either homology directed repair (HDR) or non-homologous end joining (NHEJ) with the latter being the more common repair mechanism. (6)

## TIMELINE OF GENOME EDITING IN PLANTS

- **1987:** Identification of CRISPR clustered repeat sequences
- **1993-1999:** Similar reports on CRISPR clustered repeats in bacteria and archaea
- **2000:** Identification of CRISPR spacers in bacteria and archaea
- **2002:** Term CRISPR coined Identification of Cas genes
- **2005:** CRISPR spacers found to be derived from preexisting extra chromosomal sequences
- **2007:** First experimental evidences that

CRISPR provides adaptive immunity against foreign elements

- **2008:** Programming of the first artificial CRISPR arrays to target lamda phage
- **2010-11:** Role and components of the CRISPR/Cas9 system identified
- **2012-2013:** First demonstration of SpCas9 mediated gene editing in human and mouse cells
- **2013:** Implementation of SpCas9 gene editing via transient expression in protoplast and in plants
- **2014:** First stable transgenic plants edited via SpCas9
- **2015:** Use of SaCas9 for genome editing in plants
- **2015:** First DNA free genome edited plants obtained via CRISPR/Cas9 ribonucleoprotein complexes
- **2017:** First DNA experimental evidence of use of Cpf1, Csm1 and C2c2 for genome editing of plants
- **2020:** Nobel Prize in Chemistry awarded to Emmanuelle Charpentier and Jennifer Doudna 'for the development of a method for genome editing

## METHODS OF GENETIC MODIFICATIONS IN PLANTS

- Agrobacterium-mediated gene delivery
- Post-Transcriptional Gene Silencing by RNAi
- Genome Editing with TALEN
- Genome Editing by CRISPR/Cas

### Major Steps in Genome Editing

- Vector construction
- Agrobacterium mediated transformation
- DNA extraction and sequencing
- RNA extraction and RT-PCR

### Delivery of Genome Editing Nucleases Into Plant Cells

The three major methods of genetic transformation in plants are: *Agrobacterium*-mediated transformation,

biolistics and protoplast transfection.

## CHALLENGES OF GENOME EDITING IN POTATO

Potato is vegetatively propagated, highly heterozygous, polyploid crop. Since cultivated potatoes are tetraploid, the functional approach of genes by molecular genetics is very difficult. Similar to other plant species in which the CRISPR/Cas9 has been successfully used, gene transformation in potato is efficient, and the genome sequence of double-haploid DM and diploid RH is available, which made potato an ideal candidate for this genome editing system. We face following problems during the genome editing in potato crop.(5)

- Difficulty in target designing for genome editing
- Difficulty in obtaining homozygous mutants with all target genes mutated
- Difficulty in transformation and regeneration in tissue culture
- Protoplast transformation and regeneration of plants from leaf protoplasts can lead to somaclonal variations
- Development of inbred lines due to self incompatibility that hinders the fixing of gene edits and selection of progeny by segregating out the inserted foreign gene

## USE OF CRISPR/CAS9 TECHNOLOGY IN POTATO BREEDING

In potato, CRISPR/Cas has been demonstrated for tuber quality, disease resistance (late blight and potato virus Y), phenotype, and other traits. Genetic modification has been highly successful in potato with commercialization of improved varieties for quantitative traits, such as productivity, and qualitative traits, such as disease resistance and nutritional quality. Some important characteristics of potato which can be modified with advance biotechnological tools are as follows

- Modification of Starch Composition of Potato
- Improving post harvest shelf life in potato
- Acrylamide Content
- Resistance to Phytophthora Infestans
- Resistance to Colorado Potato Beetle
- Resistance to Herbicides
- Resistance to Abiotic stresses
- Reduction of enzymatic browning in potato tubers
- Production of SGA Free Potato

**Table:1 Successful examples of application of CRISPR/Cas genome editing technology in potato**

| S.No.                           | Trait                        | Target gene                                                 |
|---------------------------------|------------------------------|-------------------------------------------------------------|
| <b>Biotic Stress Resistance</b> |                              |                                                             |
| 1.                              | PVY, PVS, and PVA resistance | P3, CI, NIb, or CP (RNA virus genes)                        |
| 2.                              | Late blight resistance       | StDND1, StCHL1 and StDMR6-1 (S-genes: Susceptibility genes) |
| 3.                              | Late blight resistance       | Caffeoyl-CoA Omethyltransferase (StCCoAOMT)                 |
| <b>Abiotic stress tolerance</b> |                              |                                                             |
| 4.                              | Phosphate transport (roots)  | StMYB44 (MYB transcription factor)                          |
| <b>Tuber quality traits</b>     |                              |                                                             |
| 5.                              | Starch quality               | GBBS, GBSS I, GBSS I                                        |
| 6.                              | Starch biosynthesis          | Starch synthase gene (StSS6)                                |
|                                 | Starch quality               | Starch-branching enzymes (SBEs) genes SBE1, SBE2            |
| 7.                              | Carotenoid biosynthesis      | PHYTOENE desaturase (PDS), StPDS, PDS and coilin            |
| 8.                              | Glycoalkaloids               | St16DOX                                                     |

|                                                |                                 |                                                                   |
|------------------------------------------------|---------------------------------|-------------------------------------------------------------------|
| 9.                                             | Steroidal glycoalkaloids (SGAs) | Sterol side chain reductase 2 (StSSR2)                            |
| 10.                                            | Enzymatic browning              | Polyphenol oxidases (PPOs) gene (StPPO2)                          |
| <b>Phenotype</b>                               |                                 |                                                                   |
| 11.                                            | Phenotype                       | StDMR6-1 and StGBSSI, StIAA2                                      |
| <b>Herbicide tolerance and incompatibility</b> |                                 |                                                                   |
| 12.                                            | Herbicide tolerance             | Acetolactate synthase1 (StALS1), StALS, StALS2, StALS1 and StALS2 |
| 13.                                            | Selfincompatibility             | Stylar ribonuclease gene (S-RNase), S-RNase                       |

## APPLICATIONS OF CRISPR/CAS9 IN POTATO CROP

### 1. Gene knockouts

CRISPR/Cas9 technology is used for gene knockouts in plants and for elucidating the function of single or multiple gene targets (*e.g.*, enzyme genes or microRNAs) *via* gene mutation.(2)

2.HDR gene knock-in and gene replacement

3.Biotic and Abiotic Stress Resistance/Tolerance Traits. CRISPR/Cas has emerged as an alternative and efficient technology to accelerate potato breeding for abiotic and biotic resistance.(3)

### 4. Transcriptional regulation

5. Tuber Quality, Phenotype, and Other Traits. CRISPR/Cas studies have been reported in potato for traits like improved tuber starch quality, carotenoid biosynthesis, glycoalkaloids, and enzymatic browning.(4)

## CONCLUSION

Genome-editing technology is increasingly

being used in plants. Overall, designs of potato that apply genomics, particularly genome editing and genomic selection, and other omics are inevitable in the future. Since modifying a specific genetic locus is an efficient method for improving breeding.

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## UNDER EXPLOITED ORNAMENTAL CROPS : TREASURE FOR FLORICULTURE INDUSTRY

Shaik Rehana\* and Madhu Bala

Department of Floriculture and Landscaping, Punjab Agricultural University,  
Ludhiana, Punjab, India

\*Corresponding Author E-mail– [rehana0124@gmail.com](mailto:rehana0124@gmail.com)

### ABSTRACT

The floriculture industry has been experiencing a rapid change with growing demand for ornamentals as consumer preferences are changing with time. In the competitive export market, cut flowers and foliage play a crucial role in stabilizing and expanding market share. The existence of enormous genetic diversity and varied agro-climatic conditions provide tremendous scope for diversification of novel ornamental crops, which fetch premium prices and possess a huge potential for the future global floriculture industry with their novelty and diversity. In this context, the introduction of potential under-exploited crops helps to meet the ever-increasing demand of the global floriculture industry. There are many promising ornamental plant species that remain unexplored and unexploited as they are cultivated mainly in rural communities that include heliconia (*Heliconia psittacorum*), bird of paradise (*Strelitzia reginae*), red ginger (*Alpinia purpurata*), lisianthus (*Eustoma grandiflorum*) among the cut flowers and peacock fern (*Selaginella wildenowii*), butchers broom (*Ruscus hypophyllum*), *Eucalyptus gunnii* and *Leucadendron* are the foliage crops that have the potential to contribute for increasing the national economy. Introducing a new ornamental crop requires investigations on various production and post-production aspects and that could open the door for the successful commercialization of these potential species and hybrids for export purpose.

**Keywords:** Minor crops, ornamentals, crop diversification, cut flowers, foliage

### INTRODUCTION

Underutilized or underexploited crops are the species with potential for contributing to food security, health (nutritional or medicinal), income generation and environmental services. These type of flower crops are neither grown commercially on large scale and nor traded widely (11). Moreover, presently only one-fourth of the crops are being utilized as major crops and the rest are named as minor, underutilized, rare flowers, wild edible flowers, etc. Underutilized or wild

flowers may not be widely known outside of a specific area or region for a variety of reasons and they are grown mostly in rural areas (23). Under-exploited or neglected crops are indigenous or exotic ancient crop species grown and consumed at some level within the local, national as well as international communities without complete cultural information which have the potential to contribute to increasing the national economy (13). These crops represent an important component of rural communities in different

parts of the world but their poor marketing and production conditions make them largely under-utilized in economic terms. They are mostly found in wild habitats and have the potential to generate income through minor crop improvements (45). These crops are traditionally grown by people in rural areas for diverse uses like food, fiber, fodder, oil or medicinal properties. However, these species have enormous potential to ensure food security, nutrition, health, income generation and environmental services (9).

Features of under-exploited crops: Under exploited crops are the traditional crop species cultivated in a specific geographical area with indigenous knowledge whose distribution, biology, cultivation aspects and uses are poorly documented. These crops are mostly linked with the cultural heritage of their places of cultivation and are locally important with a variety of traditional uses viz., ornamental, nutritional, medicinal and industrial, etc. (39). These crops are highly adaptable to extreme environmental conditions and threatened habitats with high genetic tolerance to biotic and abiotic stresses as they are mostly introduced from forest ecosystems which demands for the requirement of little or no external inputs for their cultivation (33).

## IMPORTANCE IN THE FLORICULTURE INDUSTRY

Under-exploited crops are low input crops with high commercial values. These crops play a major role in increasing the income and livelihoods of traditional communities particularly in rural areas of India with their diverse uses (23). The introduction of novel flower crops helps in crop diversification as the local and international markets are saturated with traditional flowers. With the advent of globalization, the demand for modern flowers is increasing among the consumers as the trend of saying it with flowers is increasing and the price of these flowers depends on their

demand and varies accordingly. Under exploited crops help in enriching the cultural biodiversity of rural people as every flower is related to a particular culture (Lord Krishna-Kadamba (*Neolambrackia kadamba*), Lord Indra-Lotus (*Nelumbo nucifera*), Lord Shiva-Bael (*Aegle marmelos*), Lord Saraswati-Kachnar (*Bauhinia variegata*), etc. Growing under-exploited crops during off-seasons not only satisfies market demands but also helps in employment distribution along with stabilizing farm income throughout the year. These crops are adapted to extreme environmental conditions and highly tolerant to drought, waterlogging, heat and salinity (45). A good number of under-utilized crops can enhance soil health and soil productivity which can be successfully grown in problematic and hilly areas to conserve the soil in a sustainable way. Under-exploited crops can contribute to food security, income generation and environmental services when properly utilized (3).

As local and international markets are saturated with traditional flowers, introduction of new crops helps to satisfy special market demands with their novelty in respect of their colour, form and texture (10). The introduction of these crops helps to reduce the risk of shortage of major flowers or the over-dependency on very limited numbers of major flowers (54). These novel crops help to increase the sustainability of agriculture through minimal input usage. Under-exploited crops help the poor for subsistence and income generation as they are less input demanding and relatively easy to cultivate with little attention (23). These minor flowers can be grown in marginal and wastelands of India to meet the ever-increasing market demands. Most of the minor flower's bloom throughout the year. So, these flowers can be grown round the year to satisfy the consumers during off-seasons (9).

Opportunities for expansion of new cut flowers and foliage: India is endowed with

various agro-climatic conditions in which tropical, sub-tropical and temperate conditions spreads over seasons which are best suitable to grow various flower crops (13). Along with that, the availability of ample resources such as land, abundant water and skilled labour at cheaper prices is also an advantage to the Indian floriculture industry. India is geographically located with proximity to international markets like Europe, Middle East and Japan etc. where Indian cut flowers are sold throughout the year. India is enriched with various cultures and traditions, so there is a continuous demand for flowers throughout the year in the domestic markets. The conservation of novel flowers in a specific geographical region enriches cultural diversity which also brings more income to the rural people through eco-tourism (3). Viable diversification from traditional crops during off-seasons can be possible with the cultivation of under-exploited crops. Introduction of novel crops provides an opportunity for sufficient utilization of locally available indigenous flora. Barren and unproductive lands in the marginal and hilly areas can be successfully conserved for flower cultivation (9). Local and international markets are saturated with all traditional flowers; therefore, expansion is possible for many new floriculture crops that fetch high income per unit area than other horticulture crops and availability of various government policies and schemes for the promotion of floriculture business is also an added benefit to the Indian floriculture industry (33).

## **POTENTIAL CHARACTERS OF UNDER-EXPLOITED CROPS**

Majority of the under exploited ornamental crops are attractive to consumers with vibrant colours and novel forms. They are highly adaptable to a wide range of agro-climatic conditions with high genetic

diversity. These crops are relatively easy to cultivate and adopted to existing market channels. Prolonged production is possible with supply of flowers round the year (18).

## **FACTORS TO BE CONSIDERED BEFORE INTRODUCTION**

**Floral attributes:** Various ornamental attributes such as overall attractiveness as a cut flower, uniqueness, stem length, uniformity of individual flowers, flower colour, use potential (centerpiece or filler use), fragrance, harvest (timing and duration), vase life, post-harvest quality (need for preservatives, temperature requirements, ethylene tolerance) and period of availability etc. are to be considered before introducing a crop for commercial cultivation.

### **Production aspects**

Among production aspects, adaptability of a crop to various agro-climatic conditions and its growing conditions such as open or greenhouse cultivation, hardiness of crop to biotic and abiotic stresses, adaptation to low-input agriculture, duration of crop, yield potential, tolerance to abiotic stresses (heat, chilling, drought and salinity), resistances to biotic factors (pests, diseases and parasitic weeds), water use efficiency, enhancing biological nitrogen, method of harvesting (manual/mechanical) etc. are to be evaluated.

**Economic aspects:** Cost of propagation material, production methods (greenhouse or open field), ease and cost of production, market opportunities, distribution channels, price and cost-benefit ratio are to be calculated before recommendation in a particular crop (45).

## **UNDER-EXPLOITED ORNAMENTAL CROPS AND POTENTIAL**

### **Annual flowers**

**Bells of Ireland (*Molucellalaevis*, Lamiaceae):** It was originated in western

Asia, Turkey, Syria and the Caucasus which produces green, fragrant flowers with potential as cut flowers, dry flowers, flower arrangements, bouquets and borders. It is propagated through seed and it takes 14 weeks from planting to harvest and the vase life is 7-10 days (39).

**Cock's Comb (*Celosia argentea*, *Amaranthaceae*):** It was native to Tropical Asia. The plant produces large crested flower heads like comb and long feathery spikes useful for bedding, borders and pots and as the cover plant in the shrubbery. Dried flower heads can be best suitable for table decoration and vases as they retain colour for long time (1). Major cultivated species are *Celosia plumosa*, *C. argentea*, *C. childsii*, *C. floribunda*, *C. spicata* and *C. thompsonii*. This crop is propagated through seeds that can be sown during January-February and May-June.

**Corn Cockle (*Agrostemma githago*, *Caryophyllaceae*):** It was originated in Europe. This flower can be useful as a cut flower in flower arrangements. Problems associated with this flower are poor seed germination, cannot tolerate heat, produces weak stems with a poor vase life of 7 days (30).

**Corn Flower (*Centaurea cyanus*, *Asteraceae*):** Diverse uses of corn flower include cut flower, border planting, anthocyanin extraction from petals to use as a food additive and dried petals can be used to add colour to the drinks (teas) or foods. The plant can be often used for phytoremediation of soils contaminated with lead. This was native to Europe and commercially propagated through seeds that are sown during early to mid-spring (28).

**Godetia (*Clarkia amoena*, *Onagraceae*):** It offers diverse uses to be exploited as cut flower, pot plant, edging purpose, flower border and container planting. This flower was native to North America with a blooming period of 30-60 days and flowers

last for 7-10 days after blooming (48).

**Globe Amaranth, Bachelor's Button (*Gomphrena globosa*, *Amaranthaceae*):** This crop is indigenous to India. *Gomphrena* is propagated through seed than can be sown during February-March and May-June. This plant can be suitable for beds and borders and very useful for cut flowers and dry flowers as they retain colour naturally. Dwarf varieties are used for edging or rock gardens (6).

**Larkspur (*Delphinium* sp, *Ranunculaceae*):** Larkspur can be grown for cut flower (vase life: 4-12 days), dry flower and window boxes which are widely distributed in the Northern hemisphere & South Africa. The juice of *D. consolida* flowers is mixed with alum to generate blue ink. This plant is highly poisonous as the seeds contain alkaloids (1.4%) (6).

**Lisianthus (*Eustoma grandiflorum*):** *Eustoma* belonging to *Gentianaceae* and originated in Central America and Texas is one of the potential flowers to be exploited in floriculture as a cut flower, bedding purpose and pot plant. Major cut flower qualities of *lisianthus* include the availability of more than 70 varieties with vibrant colours and petal shapes, tolerance to heat (up to 30°C), less ethylene susceptibility with a long keeping quality of 12-25 days (19). *Lisianthus* flowers are quite similar to those of tulip so it has the potential to compete with tulip for its beauty even the double types contain 10-20 petals that represent a rose-like appearance when fully open (1). This flower was first introduced in Japan in 1933 and has been reported as the number one cut flower in 2001 with over 129 million flower stems sold per year. In Europe, it is ranked as one of the top 10 cut flowers whereas, in India, *Lisianthus* is a relatively new cut flower and production is concentrated in limited area in a Bangalore (KN) and hill stations of Ooty and Kodaikanal (TN). Major producers are Japan, China, Bangladesh, Europe and Brazil. It can be

propagated through seed, stem cuttings and Micropropagation. Limiting factors in the cultivation of lisianthus are raising seedlings is difficult as the seed is very fine and germination also specific to temperatures of 22-25°C and pH range of 6.3 to 6.7 (23). Production time is also very long as it takes 5 to 6 months from planting to flowering. The flowering season is limited from summer to early autumn and growth and quality are variety specific (4).

**Ranunculus (*Ranunculus asiaticus*, Ranunculaceae):** Originated in Central Asia with production in Europe, China, South Africa, Israel, Japan and major export is from Kenya, South Africa, Zimbabwe. In India, it is widely distributed in all Northern & North Eastern states. It can be exploited as a cut flower, pot plant and for bedding purpose in gardens. But the major drawback is the very less vase life of 5 days (23).

**Snapdragon (*Antirrhinum majus*, Plantaginaceae):** Rocky areas of Europe, the United States and North Africa are the original homes of Snapdragon. It produces highly fragrant flowers on spikes to use as cut flowers, ornamental plants in borders and flower beds. The flowers also yield green coloured dye and seeds are used for oil extraction. The flower spikes are highly sensitive to ethylene (vase life: 5-7 days) and geotropic bending for which it has less acceptance in the floriculture industry as a cut flower (23).

**Statice (*Limonium sinuatum*, Plumbaginaceae):** It has diverse uses as a cut flower (Longevity: 7-14 days), filler flower, dry flower and essential oil extraction (Aromatherapy) (11). This flower was originated in the Mediterranean region with major cultivation in Europe, Asia, Africa, Australia, North America and India (Andhra Pradesh, Karnataka, Tamil Nadu, Kerala, Madhya Pradesh, Maharashtra, Uttar Pradesh, Punjab and the North eastern states).

## Perennial flowers

**Barleria (*Barleria cristata*):** This flower was originated in India and Arabia belongs to family Acanthaceae. India has wide distribution of more than 21 species spreading over West Bengal, the Deccan Plateau, North Eastern Himalayan region, Andhra Pradesh, Karnataka and Madhya Pradesh (48). The plant is a dwarf shrub suitable in mixed borders or as ornamental hedges in sunny areas. Flowers are used for temple offerings and hair decoration. Leaves of *Barleria opaca* are used as vegetables. seeds are used as antidote for snake bite, the roots and leaves are used to reduce swelling and an infusion is given for cough. Major cultivated species are *B. flava*, *B. cristata*, *B. gibsonii*, *B. strigose* and *B. tomentosa* which can be propagated through both seed and cuttings. Blooming season varies from April to September (10).

**Bird of Paradise or Crane Flower (*Strelitzia reginae*):** It belongs to the family strelitzaceae with an origin in South Africa. This flower is gaining popularity as a cut flower because of its brilliant orange and blue flowers that resemble an exotic bird peeking out from the broad leaves along with long vase life (7-10 days) with adaptability to full sun to semi-shade and flower several times in a year (7). This plant is useful in the landscape as a shrub border, mass plantation, specimen plant, indoor pot plant and alongside of water bodies. Commercially grown in countries like California, Florida, Hawaii, Israel and South Africa. Bird of Paradise is grown in sub-tropical and sub-temperate regions of India such as Andhra Pradesh, Kerala, Bangalore and adjoining areas in Karnataka and Himachal Pradesh, Sikkim, Kalimpong and Darjeeling in West Bengal, Nilgiri hills in the Western Ghats, etc. The plant is hardy and tolerant to pests and diseases. It is commonly propagated through seed, separation of offsets and division of clumps out of which vegetative propagation is commercially followed as seeds

take a longer time to establish and it may take 5-7 years to give economic *yield*. The established and healthy plants may yield 10-15 flowers in a year and the price of an individual flower ranges between Rs. 10-40 (2). Commercial production of *Strelitzia* is restricted to few countries; hence it is essential to extend its cultivation to other countries for popularization. The heavy weight of flowers, narrow genetic diversity and also limited growing conditions limiting its cultivation. Hence, there is an urgent need to develop varieties and pre and post-harvest technologies to optimize its cultivation in a larger area.

**Boronia (*Boronia heterophylla*, Rutaceae):** This flower is native to Australia and bears highly fragrant flowers to use as cut flowers (*B. heterophylla* cv. Purple Jared) and also for essential oil (*B. megastigma*) extraction to use in aromatherapy. Major production is from Australia (Lipstick var.) and major markets are Southeast Asia, Europe & Canada. This flower is commercially grown in Tasmania for the production of high-value floral extract. It is propagated through seed and plants generally flower 12 to 15 months after planting and may yield 8-12 stems/plant in the first year and 20-30 stems in the second year increasing to 30-60 stems in the third and fourth year with an economic yield up to 5-8 years. The flowers are very delicate and may be prone to wind damage and the blooming period is also limited to 2-3 weeks (September-October) along with limited colour ranges are the drawbacks related to this crop (8).

**Cape Flower (*Nerine* sp., Amaryllidaceae):** This was originated in South Africa and has the potential to use as a cut flower in flower arrangements because of prolonged longevity of 10-14 days and also useful as a pot plant. The flower has a short scape length and multiplication rate also very low along with a limited colour range,

hindering its commercial exploitation in floriculture (30).

**Cape Jasmine or Pin wheel Flower (*Tabernaemontana* spp., Apocynaceae):** It produces highly fragrant flowers in clusters to use as cut flower or oil extraction. The plant is useful in landscaping as flowerbed, border, hedge or screening purpose and container planting. Preparations from *T. sananho* are used in native medicine to treat eye injuries and as an anxiolytic and *T. heterophylla* extracts are used to treat dementia in the elderly. This flower was native to India and tropical America and Africa and propagated mainly through cuttings.

**Common Yarrow (*Achillea millefolium*, Asteraceae):** This flower has excellent potential in the floriculture industry to use as cut flower (major *sps* are *A. filipendulinam*, *A. millefolium* and *A. ptarmica*), dry flower, filler, container growing, ground cover and xeriscaping as this crop is highly tolerant to heat, cold, low soil fertility and drought (13). This plant is a heavy metal accumulator aiding in phytoremediation (29). It was originated from temperate regions of the Northern Hemisphere in Asia, Europe & North America. Yarrows can be propagated from seed, divisions, or tip cuttings. Whereas, divisions and tip cuttings are mostly preferred to maintain genetical purity of hybrids. Major drawback in its exploitation is the very low vase life of 3-4 days (13).

**Daffodil (*Narcissus pseudonarcissus*, Amaryllidaceae):** This flower has origin in Southern Europe and North Africa with major production from the UK. It has the potential to grow as a cut flower as it has a prolonged blooming period of 4-6 weeks and in the landscape also useful for pot culture and bedding purposes. The flower stems exude mucilage containing alkaloid Narciclasine that can kill the other flowers in vase (Eg: Rose, Tulip) which is a major bottleneck

limiting its usage in floristry (5). The flowers are also short-lived with a life span of 4-6 days (ethylene sensitive).

**Fire Lily (*Cyrtanthus* sp., *Amaryllidaceae*):** This was native to South Africa and widely distributed in Cape Province of South Africa with ornamental uses as a cut flower, flower arrangements and pot planting (30).

**Fritillaria (*Fritillaria imperialis*, *Liliaceae*):** This flower has been widely cultivated in China, Himalayas (India, Nepal, Pakistan), Japan, Korea and South East Asia to use as cut flower, pot plant whose origin is Northern hemisphere (9).

**Geranium (*Pelargonium* sp., *Geraniaceae*):** Geraniums are herbaceous perennials originated from South Africa. They are grown as potted plants for their handsome flowers borne in clusters and best suitable for hanging baskets and window boxes. Flowers are famous for their oil and scent (48). Cultivated sps are *P. zonale*, *P. peltatum*, *P. domesticum*, *P. grandiflorum*, *P. graveolens* and propagated through stem cuttings.

**Heliconia (*Heliconia psittacorum*):** Heliconia commonly called wild plantain or false bird of paradise belonging to family heliconiaceae has been originated in Central America. The plants produce dark red or yellow-orange pendent inflorescence with spiraled bracts that alternate in a single plane and support the numerous small flowers which are best suited as cut flowers because of their brilliant colours, exotic form, long, straight peduncles and excellent postharvest characteristics (vase life: 7-21 days), tolerance to biotic and abiotic stresses (high drought tolerance) (10). The flowers can also be grown as specialty cut flowers that represent youth and pride. It is also useful in landscaping as a hedge. Heliconia plant is a potential phytoremediator of Cr. Major producer and exporting countries are Colombia, Costa Rica and Brazil. In India, it is commercially

cultivated in southern states like Andhra Pradesh, Tamil Nadu. It can be propagated through seed, rhizomes and micropropagation among which rhizomes are mostly preferred. The price of a single cut flower ranges between 5 to 20 Rs. and the individual sucker costs about 20-50 Rs. in the Indian market. The plant produces 10-14 flowers per year depending on the variety planted which can generate an income of around Rs. 25,000-90,000/ha/year. Some important cut flower sps are *H. psittacorum*, *H. bihai*, *H. spathocircinata*, *H. rostrata*, *H. wagneriana*, *H. stricta* and *H. humilis* (4). Major drawbacks are size and heavy weight of flower stems, storage requirements and shelf life in the vase are the problems encountered by growers (28).

**Hydrangea (*Hydrangea* sp., *Hydrangeaceae*):** One of the important pH indicator plants which is commonly used to test the soil pH status. This plant yields blue flowers in acidic soils and red in case of alkaline conditions based on which corrective measures are to be followed. It is native to Japan with wide distribution in Asia and America. In Colombia, it ranks 2<sup>nd</sup> in terms of production and 5<sup>th</sup> in terms of export. Hydrangea sps has the potential as cut flower, garden and pot plant and its petals are also used for making herbal tea (32). The major limiting factor in its commercial exploitation is sepal browning leading to flower wilting shortly after harvest (28).

**Lachenalia or Wild Hyacinth (*Lachenalia bulbifera*, *Hyacinthaceae*):** It has origin and distribution in the Western Cape of South Africa and Namibia. This flower can be useful as a cut flower, pot plant and in garden decoration (bedding) but major drawbacks include low adaptability, growth and flowering are climatic specific and highly susceptible to viruses (8).

**Lotus (*Nelumbo nucifera*, *Nymphaeaceae*):** One of the sacred aquatic

plant native to India that adds beauty to landscape, particularly in large waterways, lakes, ponds, etc. Flowers are commonly used for religious and ceremonial offerings. Underground rhizomes called as Phool Makhana are used as vegetable, usually cooked, fried or preserved in vinegar. The filaments of *N. nucifera* known as kinjalka are astringent and has cooling properties. Commercially important species are *N. lutea* and *N. nucifera*. It can be propagated by Rhizomes or seeds during March-April.

**Peonies (*Paeonia officinalis*, *Paeoniaceae*):** Peonies are the most attractive flowering plants with origin and cultivation in Asia, Europe and North America as cut flowers, garden plants and for medicinal purpose. They are commercially propagated through crown/root divisions and the economic yield starts three years after planting which continues up to 25 years. Peonies dried in both bud and blossom retains good color and shape (18). The double types are used in Victorian-style winter bouquets, and the single and semi double types are used in contemporary arrangements. This flower has a very limited vase life (5-7 days) and a short flowering season from late spring to early summer (Apr-May/June).

**Phlox (*Phlox paniculate*, *Polemoniaceae*):** Native to North America and has the potential as cut flower (diverse colours), hedge or edge, flower bed, filler, containers or window boxes but it has a very short vase life of 7-10 days.

**Protea (Sugarbush or Honey plant):** Proteas are a group of emerging cut flowers belonging to family Proteaceae with origin and distribution in southern continents like South Africa, Australia, South America, Spain, USA, California and Hawaii. The plant produces characteristic large, oval flowers with vibrant colours (light pink, pinkish-red, white) which are ideally suited as focal or centerpieces of large floral arrangements and can also use as

dry flowers after losing freshness (29). Flowers are surrounded by brightly coloured bracts, covered in silky hairs which are very attractive and remain fresh for 2-3 weeks. Important attributes of proteas for commercial cultivation include their wider adaptability to various climates with extremely low fertilizer and input requirement, low initial investment, easily propagated by cuttings, less demanding plants once established, relatively high yielding with good market potential. Commercially important genera of Proteaceae are Protea, Lecucospermum, Leucadendron and Banksia (33).

**Red Ginger (*Alpinia purpurata*):** Red ginger is an evergreen, perennial herb that originated in Tropical Asia and belongs to family Zingiberaceae with major production from Bangladesh, Colombia, Costa Rica, Brazil, India (South and North Eastern states) and major markets are Italy, the United Kingdom and France. The plant produces bearing long, fragrant inflorescences of bright red-pink coloured bracts which are best suited as cut flowers in floral arrangements (45). In landscape also best suitable as hedge or screening purpose and roadside plantation. The flowers are available round the year with a vase life of 10-14 days which have the potential to fetch Rs. 40 per stem. It can be propagated through seed, offshoots and rhizomes. The major factors limiting its commercial exploitation are bract browning, geotropic bending and chilling injury when flowers are stored at less than 12°C (18).

**Safflower (*Carthamus tinctorius*, *Asteraceae*):** This flower was distributed in parts of Asia and Africa which produce globular flower heads (bright yellow, orange or red flowers) with prolonged blooming period of 4-6 weeks. This crop can tolerate a wide range of temperatures from -7 to 40°C (day-neutral plant). The flowers are commercially grown as cut flowers for floral arrangements in Western Europe, Japan, Latin America and Kenya and

can also processed as dry flowers after use (13). Two major pigments Carthamidine (yellow) and Carthamine (red) extracted from stigmas are used for colouring and flavouring foods, textile industry and cosmetics in China. Edible oil (14.8-25.9% Linoleic acid) from seeds is used for cooking (49). The flowers are used as a cheaper substitute for saffron in India and leaves can be used as a vegetable and also for making herbal teas and medicinal purposes in China (14). This crop is commercially propagated through seed with a seed rate of 9-11 Kg/acre. The major drawback with this crop is the presence of spines which is limiting its usage in the floriculture industry. So, in the future, there is tremendous scope to produce spineless plants to grow as cut flowers in India and China.

**Sweet William (*Dianthus barbatus*, Caryophyllaceae):** It is native to Southern Europe and parts of Asia and has the potential as a cut flower (vase life: 7-18 days) in flower arrangements and in ornamental gardens as borders, mass planting and rock garden etc.

**Star-of-Bethlehem or wonder-flower (*Ornithogalum thyrsoides*, Asparagaceae):** This flower was originated in Cape province in South Africa and distributed all along the South Africa and Namibia. It can be an excellent cut flower (vase life: 14 days) in flower arrangements and pot culture (8). But it has a slow propagation rate and is highly susceptible to virus (Mosaic).

**Wax Flower (*Chamelaucium uncinatum*, Myrtaceae):** Wax flower can be grown as a cut flower (fragrant) and indoor pot plant. It is native to Australia and cultivated in California, South Africa, Australia, Myanmar, Thailand, Peru and India (N-E states, Kerala) with major markets in Europe (50). The flowers are specific to June-November flowering with a vase life of 5-9 days.

**Wind Flower or Poppy Anemone**

**(*Anemone coronaria*, Ranunculaceae):** It is one of the emerging cut flowers in Iran. The stem terminates into an attractive single, velvety, cup-shaped flower with a darkish center and petals are enclosed in a circle of green sepals enabling it as an excellent cut flower (30). In landscaping is also useful for border planting, flower beds, container gardens, etc. It was originated in Western Asia and possibly the Mediterranean region and widely distributed among the Indian states viz., Sikkim, Jammu and Kashmir, Himachal Pradesh, Andhra Pradesh, Uttarakhand, Nagaland, Meghalaya, Tamil Nadu and Punjab. Because of its poor vase life (5-8 days), low-temperature specificity, longevity and stem bending make it mostly under-utilized (6).

## POTENTIAL FOLIAGE CROPS

Foliage are the plants that are grown primarily for their foliage rather than for flowers (39). Foliage are the raw materials that adds character to the design in the flower arrangements and bouquets. To be considered as a foliage crop, it should possess strong, leathery, tough and shining leaf textures with equal vase life as flowers in the arrangement (22). It should be quick growing with high productivity and free from thorns, unpleasant odour and latex (49). Some potential under-exploited foliage crops are discussed below:

**Butcher's broom (*Ruscus hypophyllum*, Asparagaceae):** This was native to Iberia and northwest Africa and used in the floral trade as cut foliage as well as pot plant (16).

**Chinese ladder break fern (*Pteris vittata*, Pteridaceae):** It is one of the potential hyperaccumulator plants for arsenic and is mostly recommended for pollution control. It produces ornamental, attractive leaves to be exploited as cut foliage (48).

***Eucalyptus gunnii* (Myrtaceae):** This plant can be grown for its lush, rounded, shiny

juvenile foliage to use in flower arrangements and also for essential oil extraction. The stems are easy to use and remain fresh for longer period (19).

***Juniperus communis* (Cupressaceae):** This plant can be seen in Europe, Southwest Asia and North America. These are the most popular conifers to be cultivated as ornamentals for parks and gardens, cut foliage, timber, culinary and essential oil extraction.

***Leucadendron* cv “Safari Sunset” (Proteaceae):** It belongs to the protea group which is commercially cultivated in South Africa, New Zealand, Australia for cut flower and foliage (8).

**Maiden hair fern (*Adiantum raddianum*, Pteridaceae):** This was originated in South America and widely distributed in India, Sri Lanka, Mauritius, Mexico, South America. Many sps of *Adiantum* are known for growing on rock walls around waterfalls and water seepage areas and also as an indoor plant. The cut foliage can be exploited for ornamental purposes in floral arrangements (48).

***Monstera deliciosa* (Araceae):** Native to tropical regions of America. One of the best indoor house plants to be grown for its foliage. Produces edible leaves that taste like a combination of banana and pineapple fruits.

**Peacock fern (*Selaginella willdenowii*, Selaginellaceae):** This plant can be seen in tropical and subtropical regions of America. The foliage of this plant emits blue colour iridescence produced by a thin layer of cells with lamellar structure in the upper cuticle of leaves as an adaptation to strong sunbeams filtering through the canopy that would damage shade-adapted species. So, it produces blue-coloured leaves as an adaptation to high light intensity. The attractive, novel-coloured leaves can be better exploited for foliage purpose in floristry (48).

***Selaginella delicatula* (Selaginellaceae):** Selaginellas were widely

distributed in China, India, Bangladesh, Nepal, Burma, Taiwan, Philippines, Malaya, New Guinea and Polynesia. These are commonly seen on stone walls, along roadsides and shady places in coastal Karnataka and the western ghats which has the potential as cut foliage (45).

**Silver fern (*Pityrogramma calomelanos*, Pteridaceae):** It was originated in Tropical and sub-tropical America and distributed throughout the tropics, including South-East Asia. It can be grown as an ornamental plant or for cut foliage purpose (48).

**Silver oak (*Grevillea robusta*, Proteaceae):** Native to Eastern coastal Australia. Mostly grown in the landscape for screening purpose, cut foliage and timber production.

**Soft fern (*Christella dentata*, Thelypteridaceae):** This fern is widely distributed in Australia & islands in the south Pacific Ocean. It can be best suited for cut foliage as a ground cover (48).

**Song of India (*Dracaena reflexa*, Asparagaceae):** *Dracaena* offers many ornamental uses as a house plant, specimen plant in landscapes as the best indoor plant to purify benzene, trichloro-ethylene and xylene from air. This plant produces ornamental, thick, shining and leathery leaves that can be best exploited for foliage purpose (54).

***Thuja occidentalis* (Cupressaceae):** One of the important ornamental plants found in landscape gardens as a hedge and can also be grown for cut foliage which is rich in vitamin-C and also for essential oil.

**Umbrella fern (*Sticherus flabellatus*, Gleicheniaceae):** It is found in Australia, New Zealand and can be grown as a house plant and for cut foliage (9).

## CONSTRAINTS IN THE EXPLOITATION OF MINOR FLOWERS AND FOLIAGE

Limited germplasm availability particularly at the national level. Information on production technology, postharvest cold chain and technical knowledge is lacking. National policies for supporting research and development of minor crops are not formulated. Interest by researchers, agriculturists, producers and extension workers is lacking. These crops are important for the subsistence of local communities, yet remain poorly documented and neglected by the mainstream research and developmental activities.

### FUTURE STRATEGIES

- Exploration & exploitation of indigenous new ornamentals
- Introduction & acclimatization of new cut flowers
- Need for providing research support on new ornamentals
- Multi-disciplinary research employing conventional and molecular tools has the potential to develop high-yielding cultivars to improve food security, environmental health and industrial applications
- Co-ordinated well focused research programs & policies of new crops for developments should be given top priority
- Information on consumer attitudes that influence floral purchasing to be collected
- Regional, national and global events involving the importance and potential of under-utilized crops should be conducted.

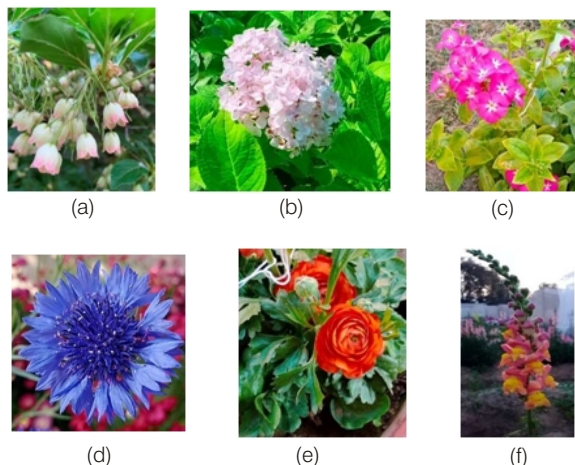


**Figure 1: Under-exploited ornamental crops [a) *Boronia heterophylla* b) *Hydrangea* spc) *Phlox paniculate* d) *Centaurea cyanus* e) *Ranunculus asiaticus* f) *Antirrhinum majus* g) *Dianthus barbatus* h) *Narcissus pseudonarcissus* i) *Anemone coronaria* j) *Ornithogalum thyrsoides* k) *Clarkia amoena* l) *Limonium sinuatum* m) *Strelitzia reginae* n) *Celosia argentea* o) *Ruscus hypophyllum*]**

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## EVALUATION OF BIOCHEMICAL DIVERSITY AMONG SINGLE AND DOUBLE PETALED *POLIANTHES TUBEROSA* GENOTYPES UNDER NORTH INDIAN CONDITION

Hemlata Bharti\*, Krishan P. Singh, Archana P. Raina and M.C. Singh

ICAR-Indian Agricultural Research Institute, New Delhi

\*Corresponding Author E-mail– [hemlatafloriculture@gmail.com](mailto:hemlatafloriculture@gmail.com), [kpsingh.dfr@gmail.com](mailto:kpsingh.dfr@gmail.com)

### ABSTRACT

*Polianthes tuberosa* L. (tuberose) is one of the most important tropical ornamental bulbous flowering plants cultivated for production of long lasting flower spikes and essential oil for making perfumes. Its essence are in high demand both in international and domestic market but the aesthetic of tuberose essential oil mainly for single and double petal type are disregarded. The present study was performed in order to assess the potential bioavailability of major compound present in the essential oil of the single and double type of flower in *Polianthes tuberosa*. The concrete and absolute content of open florets of tuberose genotypes were from 0.023 (Hyderabad Double) to 0.0603% (single pettled Shringar) and 11.775% (Hyderabad Double) to 23.69% (Shringar), respectively on fresh weight basis. All essential oils were characterised by monoterpenes hydrocarbons (0.13-2.98%), oxygenated monoterpenes (0.03-13.24%), other aromatic compounds ranged from (8.46-79.39%) especially benzyl benzoate (20.75%) which were almost dominant in all cases and with a trace amount of sesquiterpenes (0.04-0.94%). Beside benzyl benzoate, benzyl salicylate (10.85%), methyl salicylate (9.32%) and 1,8-cineole (9.24%) were generally found as the principal components of studied single pettled genotypes of tuberose. There was no relationship exists between the total yield of oil and constituent amount like benzyl benzoate as well as 1,8-cineole. For instance Shringar with highest oil content is composed of 34.55% benzyl benzoate with negligible 1,8-cineole, while Prajwal with lower oil content is with 21.24% and 8.81% (highest) of benzyl benzoate and 1,8-cineole, respectively. The strong correlation between these compounds indicates that the genotypes with high response coefficient constitute a good index for ability to produce high quality of essential oils with medicinal property.

**Keywords:** Tuberose, essential oils, diversity, Gas chromatography-mass spectrometry.

### INTRODUCTION

Tuberose (*Polianthes tuberosa* Linn.) is one of the most important ornamental plant native to Mexico belongs to family Agavaceae (15). It is largely cultivated in countries like Italy, France, Morocco, South Africa, Taiwan,

Bangladesh, India and many other tropical and sub-tropical areas of the world. Tuberose blooms throughout the year and its white waxy florets arranged on spikes are rich in pleasant fragrance; florets are star shaped, waxy and loosely arranged on spike that can reach from 30 to 120 cm in length. Concrete

and absolute are two important perfumery products of tuberose. Single genotypes (single row of perianth) of tuberose are more fragrant and commonly used for extraction of essential oils, loose flowers, making garland, etc. than double genotypes (more than two rows of perianth) used as cut flowers, garden display and interior decoration (6). The concrete is extracted by solvent extraction method and contains the fragrant principle of flowers, waxes and colouring and albuminous matters. The absolute is obtained from concrete by separating waxes and it represents the concentrated form of the flower perfume (11). Tuberose concrete and absolute are highly priced in international markets and their extraction has been established as export oriented agro- industry in India. India has exported one metric tonne of tuberose concrete worth of Rs 44.5 million during 2000-01 (7).

Although essential oil of tuberose is used as a perfumery material but nowadays subjected to intense research for their medicinal and antimicrobial properties (2). The oil show different biological activities including antibacterial, antifungal, antioxidant, insecticidal, herbicidal and wound healing (9, 10). The essential oil content, composition and their biological activities are influenced by intrinsic and external factors such as genetic background, genotypes used, climatic condition of cultivated crop, plant growth stages and type of plant part, postharvest processing of plant materials and method of extraction (3, 6, 14). There is a considerable chemical polymorphism in the essential oil of this plant (11, 6, 12). Research on the essential oils composition of different tuberose genotypes leads to the identification of many chemotypes in these genotypes as the major components (6). There is no comprehensive research considering variation in the recovery of essential oils of different genotypes of *P. tuberosa*. Therefore, the main aim of the present study was to determine the

substantial yield of concrete/absolute in different genotypes and also to expand the knowledge on the essential oils composition and quantification of its content, in order to find various chemotypes of this species. This study may be useful as initial materials for breeding programs and in relevant industries.

## MATERIALS AND METHODS

Ten tuberose genotypes, seven single petalled (GKTC-4, Arka Nirantara, Phule Rajani, Prajwal, Mexican Single, Shringar and Sikkim Selection) and three double petalled (Suvasini, Hyderabad Double and Calcutta Double) types were cultivated at the Research Farm of ICAR-Directorate of Floricultural Research, IARI Campus, New Delhi (28.64°N latitude and 77.16°E longitude). The weekly average of various weather parameters that prevailed during the course of investigation were recorded at Meteorological Observatory of Division of Agricultural Physics, Indian Agriculture Research Institute, New Delhi. Healthy and uniform sized bulbs (having a diameter of 2.0 to 3.0 cm) were planted at 30 cm x 30 cm spacing at 4-6 cm depth in a randomized block design with three replications. Uniform package of practices were followed to grow healthy crop. Concrete and absolute extraction was carried out at Bio-chemistry Laboratory of the Division of Germplasm Evaluation, National Bureau of Plant Genetic Resources, New Delhi.

Concrete extraction (reddish yellow waxy solid with long-lasting tenacious aroma) of tuberose was done by solvent extraction method. In this method, 2 kg florets were harvested from flowering spikes in the early morning (6-7 a.m.) and brought to the Bio-chemistry Laboratory of ICAR-NBPGR, New Delhi in muslin cloth bags. Florets were hand-plucked from tuberose flowering spikes carefully as crushing would damage the concrete because such damage can result in

the release of enzymes in the flower juice which deteriorates the quality of concrete and oil recovery. Florets were soaked in petroleum ether at 40 to 60°C for 4 h. The scent of tuberose absolute (reddish brown liquid has a warm balsamic character) extraction from petroleum ether was closer to that of natural flowers than from hexane. Petroleum ether was separated and kept aside and this step was repeated with fresh petroleum ether and the entire petroleum ether fraction so obtained was pooled. The enriched solvent from the extractor was pumped into an evaporator for solvent recovery and the solvent content was reduced to about one-tenth the original volume. The concentrated material from the evaporator is pumped into a vacuum evaporator where the solvent was removed more carefully under high vacuum.

Concretes are not widely used in perfumery in their native form but are generally converted into an alcohol-soluble volatile concentrate known as an absolute, i.e. they have to be extracted with alcohol. To make an absolute, the concrete is mixed with absolute alcohol and agitated thoroughly in a vessel with an agitator. During agitation, the temperature was kept at 40-60° C and the concrete was immersed in the solution. The solution was cooled down to -5 to -10° C to precipitate out the wax, since waxes are normally insoluble in alcohol below -1° C. The precipitated wax was removed by passing the solution through a rotary filter. The filtrate from the rotary filter was pumped into a primary evaporator, where it is concentrated to about 10% alcohol content. Finally, the concentrated extract is pumped into an agitating-type evaporator, where the alcohol is carefully removed under high vacuum which was further subjected to gas chromatography (GC) and gas chromatography mass spectrometry (GC-MS) analysis.

Gas chromatography (GC) analysis was performed using Perkin Elmer Auto System model gas chromatograph. Nitrogen was used as carrier gas at a flow rate of 1 ml/minute. A capillary column (Carbowax 20M column; length 60m, internal diameter 0.25mm i.d, film coating thickness 0.25µm) with Flame Ionisation Detector (FID) initial oven temperature of 50°C raised to 280°C @ 4°C/min and finally isotherm for 10 min. Each compound was identified by retention indices, which were determined using a C<sub>8</sub>-C<sub>22</sub> n-alkane mixture (1). All quantified constituents are reported as peak area percentage.

The qualitative analysis was performed in a Varian 4000 mass spectrometer, equipped with a CP8944 fused factor four capillary column, VF-5MS, (film thickness 0.25µm, 30 x 0.25 x 0.39 mm i.d.) oven temperature was 50-260°C at a rate of 4°C/minute, transfer line temperature 265°C carrier gas helium, split ratio 1:20. The identification of the components of the oils was performed by analysing the fragmentation patterns observed in the mass spectra, which were compared with those present in NIST-MS WILEY8 library. Mass spectra from the literature were also compared (1).

Differences in the oil content of the populations in question were tested with analysis of variance (ANOVA) and means further compared using Duncan's multiple range test at  $p < 0.05$  to determine the relationships of genotypes and hierarchical clustering were served on the basis of their essential oils composition. All constituents identified were subjected to the multi-variate analysis. To avoid the dependency of percentage data, they were standardized prior to analysis. For hierarchical clustering, the Euclidean Distance was employed to calculate the similarity between genotypes and Ward's method. Analysis of data was performed using SAS 9.3 statistical computer software.

## RESULTS AND DISCUSSION

### Comparison of concrete and essential oils content of tuberose genotypes

The experimental results showed significant variation in recovery of concrete per cent among all studied genotypes of tuberose (Table 1). The maximum concrete per cent recorded in cv. Shringar for 2012 and 2013 (0.059 and 0.060 %, respectively) and minimum in Hyderabad Double (0.023 and 0.028 %) during 2012 and 2013, respectively. An inquisition of pooled data for both the years also showed maximum value of concrete content for Shringar (0.0597 %) and minimum value for Hyderabad Double (0.0255 %).

Data analysis of both years for absolute per cent ranged from 11.775% (Calcutta Double) to 23.69% (Shringar) (Fig.1). Among studied tuberose genotypes, GKTC-4, Arka Nirantara, Phule Rajni, Prajwal, Mexican Single and Shringar showed >15% of oil yield, whereas genotypes, Sikkim Selection, Calcutta Double, Suvasini and Hyderabad Double showed <15% yield. Moreover, among these, single petalled genotypes showed only a minor variation with respect to the yield of oil. These results indicate that genotype Shringar, Arka Nirantara and Prajwal yielded higher essential oils (Fig.1) among single petalled.

### Essential oils composition of tuberose genotypes

GC and GC-MS allowed the identification of twenty constituents in the essential oils of all samples represented about 0.04 (Suvasini) to 90.89% (Prajwal) of the total composition (Fig. 2). In this study, essential oils of tuberose mainly contains monoterpenes hydrocarbons, oxygenated monoterpenes, sesquiterpenes and ten other aromatic compounds like eugenol, methyl salicylate, benzyl benzoate, benzyl salicylate, methyl isoeugenol, methyl benzoate, phenyl ethyl alcohol, indole, benzyl

isobutanoate, isoeugenol (Tables 2) variations in different classes of volatile compound.

Table 3 revealed that Monoterpene hydrocarbons ranged from 0.13% (Sikkim Selection) to 2.98% (GKTC4). The major compounds among monoterpene hydrocarbons reported are: sabinene (2.98 %),  $\alpha$ -pinene (2.35 %) and  $\alpha$ -ocimene (0.15 %) (Table 2). Genotype GKTC4 showed higher monoterpene hydrocarbon content than sesquiterpene content (0.04%) and oxygenated monoterpenes. The content of oxygenated monoterpenes was higher than monoterpene hydrocarbons ranged from 0.03% (Phule Rajani, Fig. 4) to 13.24% (Sikkim Selection). The major compounds among oxygenated monoterpene were: 1, 8-cineole (8.81 %), linalool (3.24 %),  $\alpha$ -terpineole (0.31 %) and geraniol (2.54 %). Although 1, 8-cineole was generally found to be the main constituent of Prajwal and Sikkim Selection while this compound amounted only 8.81% and 8.02%, respectively. Second most abundant oxygenated monoterpenes in oil sample obtained was geraniol which was highest and lowest concentration in the essential oils obtained from Sikkim Selection (2.54%) and Arka Nirantara (1.09%), respectively. The content of sesquiterpene ranged from 0.04% (GKTC4) to 0.94% (Prajwal).  $\alpha$ -caryophyllene and farnesol were two constituents of sesquiterpenes. Sesquiterpene present in trace amount in genotypes Prajwal (0.94%), GKTC4 (0.04%), Phule Rajani (0.79%), Sikkim Selection (0.73%), Shringar (0.07%), Mexican Single (0.05%) and Arka Nirantara (0.78%), whereas in genotypes Calcutta Double and Hyderabad Double were not noticed. Besides monoterpenoids and sesquiterpenoids, other major aromatic compounds also constitute an appreciable amount of oil compositions (8.46-79.39%) shown in Table 3 and were mainly represented by eugenol (0.32%), methyl salicylate (9.32%), benzyl benzoate

(23.52%), benzyl salicylate (10.85%), methyl isoeugenol (5.6%), methyl benzoate (6.52%), phenyl- ethyl alcohol (0.73%), indole (1.71%), benzyl isobutanoate (3.21%) and isoeugenol (0.84%). One or two of these compounds are generally dominant to the exclusion of others. Phenylethyl alcohol (1.64%) showed the highest in ArkaNirantara absolute. These results suggest that composition of monoterpene hydrocarbons, oxygenated monoterpene, sesquiterpenes and other important aromatic constituents vary among different genotypes of tuberose.

A simple correlation was computed among all of the chemical constituents present in the essential oils from studied ten genotypes (Table 4). A significant positive correlation indicating the dependence of these components on each other and in increasing the recovery of final product. This shows that the mechanism which controls these constituents may be controlled by different process.

### Cluster analysis

Based on the data from percentage composition of essential oils, in this study hierarchical clustering and PCA was used to determine the relationships between the ten studied genotypes (Fig.4) Cluster analysis grouped the ten genotypes into five main groups corresponding to their principal constituents at the level of 0.40. Members of the first group (Prajwal, Sikkim Selection and Arka Nirantara) contained eleven components namely, 1, 8-cineole, methyl benzoate, phenyl ethyl alcohol, methyl salicylate, geraniol, indole, benzyl iso-butanoate, eugenol, farnesol, benzyl benzoate and benzyl salicylate was the main constituent of essential oils. The genotype of the second group (GKTC4) contained ten constituent of essential oil. Group third form two sub clusters, such as Phule Rajani, Shringar and Mexican Single. Cultivars under same group show more similarity in the essential oils composition. Finally, genotype Calcutta

Double was placed in group four. Genotype Hyderabad Double and Vaibhav contained four similar components namely, benzylaldehyde, indole, methyl isoeugenol and benzyl salicylate as the characteristics of its essential oils.

Solvent extraction coupled with characterisation by GC and GC-MS have been proved a valuable tool for the chemo-profiling of tuberose constituents for determining the variation in the chemical composition (16, 6, 17) evaluated the concrete content of tuberose genotypes (two Single and two Double types) over two seasons i.e. March and October. They found that Single types yielded a higher concrete content (0.134-0.136 %) than the Double types (0.107-0.108 %). Also, the flowers harvested during October yielded a higher concrete content than those harvested during March. The production of concrete and absolute in North India and compared with varieties grown in South India for double and single petals type tuberose (3, 17) conducted an experiment for concrete content on Shrinagar which is a cross between Mexican Single and Pearl Double. The significant differences in the recovery of concrete content in different tuberose genotypes were also confirmed by (8, 12); in tuberose and (19) in myrtle (*Myrtus communis* L.). It has been observed that the concrete recovered from single petalled genotypes has stronger aroma as compared to the aroma obtained in concrete from double petalled genotypes (6, 18). The concrete content of Shrinagar was 0.13 % which was on par with Indole and benzyl benzoate content was found higher than Mexican Single.

Different Single petalled of tuberose genotypes in this analysis mainly consisted of benzyl benzoate (34.55%), benzyl salicylate (10.85%), methyl salicylate (9.32%), methyl benzoate (6.52%) and 1, 8-cineole (8.41%) which are the scented volatile compound used mainly in cosmetic industries (14).

According to the previous studies, the major volatiles of tuberose flowers derived from two biosynthetic pathways including shikimate and mevalonate pathway (13). Benzenoids are usually derived from phenylpropanoids in shikimate pathway including methyl anthranilate, methyl benzyl benzoate, methyl benzoate, methyl salicylate, ethyl benzoate, methyl butyl benzoate, benzyl benzoate and benzyl salicylate (5). Tuberose essential oils is mainly composed of monoterpenes hydrocarbons, oxygenated monoterpenes, sesquiterpenes and other aromatic compounds like benzyl benzoate, eugenol, phenyl ethyl alcohol, indole, methyl salicylate, benzyl salicylate, methyl isoeugenol, benzyl isobutanoate (9, 1). Among these compounds, levels of benzyl benzoate and benzyl salicylate emission reached their maximum on the day of anthesis, continued to be emitted for the next three consecutive days of post-anthesis and declined thereafter (4). Benzyl benzoate, the major component of tuberose absolute also present upto 34.55% in Shringar (11). At the same time, there was no relationship exists between the total yield of oil and constituent amount like benzyl benzoate as well as 1, 8-cineole. For instance Shringar with highest oil content is composed of 34.55% benzyl benzoate with negligible 1,8-cineole, while Prajwal with lower oil content is with 21.24% and 8.81% (highest) of benzyl benzoate and 1,8-cineole, respectively. The strong correlation between these compounds indicates that the genotypes with high response coefficient constitute a good index for ability to produce high quality of scented volatile essential compounds.

The variation in the chemical profile of essential oils may also due to genetic background and biosynthetic pathways leading to the vast diversity of plant phenolic

products and the comparison of the expression patterns with metabolite profiling in different developmental stages, tissues and environmental conditions (2). However, more studies are needed to evaluate the biological activities of the essential oils of the ten studied genotypes and the genetic base for the observed chemical variation prior to use as materials for the genetic improvement of tuberose. This study can also be very helpful for farmers to produce superior quality genotypes by choosing the right genotypes of tuberose for cultivation. This study also provides valuable information to the perfumery industry to select these genotypes containing the desired aroma profile.

**Table 1 Comparative concrete per cent recovery in different tuberose genotypes**

| Genotype         | Florets type | Origin place in India | Concrete per cent |         |        |
|------------------|--------------|-----------------------|-------------------|---------|--------|
|                  |              |                       | 2011-12           | 2012-13 | Mean   |
| GKTC4            | Single       | MPKV, Rahuri          | 0.0285            | 0.0270  | 0.0277 |
| Arka Nirantara   | Single       | IIHR, Bangalore       | 0.0572            | 0.0521  | 0.0546 |
| Suvasini         | Double       | IIHR, Bangalore       | 0.0250            | 0.0300  | 0.0275 |
| Hyderabad Double | Double       | ANGRA U, Hyderabad    | 0.0230            | 0.0280  | 0.0255 |
| Phule Rajani     | Single       | MPKV, Rahuri          | 0.0300            | 0.0310  | 0.0305 |
| Calcutta Double  | Double       | Calcutta              | 0.0290            | 0.0300  | 0.0295 |
| Prajwal          | Single       | IIHR, Bangalore       | 0.0544            | 0.0552  | 0.0548 |
| Mexican Single   | Single       | Not known             | 0.0430            | 0.0452  | 0.0441 |
| Shringar         | Single       | IIHR, Bangalore       | 0.0592            | 0.0603  | 0.0597 |
| Sikkim Selection | Single       | Sikkim                | 0.0390            | 0.0402  | 0.0396 |

**Table 2** Content of major constituents in essential oils of ten genotypes of tuberose.<sup>a</sup>

| Compound               | N | Mean   | Std Dev | Sum     | Minimum | Maximum |
|------------------------|---|--------|---------|---------|---------|---------|
| $\beta$ -pinene        | 1 | 2.350  | 0.00    | 2.350   | 2.350   | 2.350   |
| Sabinene               | 2 | 2.125  | 1.209   | 4.250   | 1.270   | 2.980   |
| Benzylaldehyde         | 5 | 0.059  | 0.018   | 0.297   | 0.035   | 0.080   |
| Linalool               | 2 | 2.960  | 0.395   | 5.920   | 2.680   | 3.240   |
| $\beta$ -ocimene       | 2 | 0.140  | 0.014   | 0.280   | 0.130   | 0.150   |
| 1,8-cineole            | 2 | 8.415  | 0.558   | 16.830  | 8.020   | 8.810   |
| Methyl benzoate        | 3 | 7.066  | 5.511   | 21.200  | 1.090   | 11.950  |
| Phenyl ethyl alcohol   | 4 | 0.955  | 0.568   | 3.820   | 0.320   | 1.640   |
| Methyl Salicylate      | 2 | 9.320  | 1.329   | 18.640  | 8.380   | 10.260  |
| Geraniol               | 5 | 1.988  | 0.593   | 9.940   | 1.090   | 2.540   |
| Indole                 | 7 | 1.785  | 0.935   | 12.500  | 0.310   | 3.120   |
| Benzyl isobutanoate    | 4 | 3.152  | 0.607   | 12.610  | 2.470   | 3.950   |
| $\alpha$ -terpineole   | 5 | 0.100  | 0.118   | 0.500   | 0.030   | 0.310   |
| Eugenol                | 5 | 0.630  | 0.722   | 3.150   | 0.100   | 1.890   |
| $\beta$ -caryophyllene | 4 | 0.415  | 0.332   | 1.660   | 0.040   | 0.780   |
| Isoeugenol             | 1 | 1.680  | 0.000   | 1.680   | 1.680   | 1.680   |
| Methyl Isoeugenol      | 7 | 4.507  | 2.516   | 31.550  | 2.390   | 8.820   |
| Farnesol               | 6 | 0.296  | 0.290   | 1.778   | 0.040   | 0.730   |
| Benzyl benzoate        | 6 | 20.758 | 7.455   | 124.550 | 12.490  | 34.550  |
| Benzyl Salicylate      | 4 | 13.850 | 4.822   | 41.550  | 9.7800  | 16.600  |

**Note:** Minimum, maximum, mean and standard deviation are shown for ten genotypes of tuberose.

All values are per cent content. N is number of genotype (s).

**Table 3** Major constituents of essential oils (absolute) including chemical classes of tuberose genotypes

|                            |         |        |       |      |      |      |       | Genoty<br>pe | Num<br>ber |      |      |      |        |
|----------------------------|---------|--------|-------|------|------|------|-------|--------------|------------|------|------|------|--------|
| Compound                   | SRI     | RI     | 1     | 2    | 3    | 4    | 5     | 6            | 7          | 8    | 9    | 10   | ID     |
| $\beta$ -pinene            | 4.733   | 4.6    | -     | -    | -    | -    | -     | -            | -          | 2.35 | -    | -    | RI, MS |
| Sabinene                   | 5.2     | 5.45   | -     | 2.98 | -    | -    | -     | -            | -          | -    | 1.27 | -    | RI, MS |
| Benzylaldehy<br>de         | 7.252   | 8.48   | -     | -    | 0.05 | -    | 0.077 | 0.055        | 0.035      | -    | -    | 0.08 | RI, MS |
| Linalool                   | 11.05   | 12.08  | -     | -    | -    | -    | 2.68  | -            | -          | -    | -    | 3.24 | RI, MS |
| $\beta$ -ocimene           | 12.031  | 12.7   | -     | -    | -    | -    | 0.13  | -            | -          | -    | -    | 0.15 | RI, MS |
| 1,8-cineole                | 16.72   | 16.25  | 8.81  | -    | -    | -    | 8.02  | -            | -          | -    | -    | -    | RI, MS |
| Methyl<br>benzoate         | 19.885  | 20.032 | 11.95 | -    | -    | -    | 10.09 | -            | -          | -    | -    | 8.16 | RI, MS |
| Phenyl ethyl<br>alcohol    | 20.6    | 22.87  | 0.71  | -    | -    | -    | 1.15  | 0.32         | -          | -    | -    | 1.64 | RI, MS |
| Methyl<br>Salicylate       | 24.2636 | 25.5   | 10.26 | -    | -    | -    | 8.38  | -            | -          | -    | -    | -    | RI, MS |
| Geraniol                   | 26.419  | 26.93  | 1.72  | -    | -    | -    | 2.54  | -            | -          | 2.16 | 2.43 | 1.09 | RI, MS |
| Indole                     | 27.874  | 27.82  | 2.29  | -    | 1.16 | -    | 1.23  | 0.31         | -          | 2.14 | 2.25 | 3.12 | RI, MS |
| Benzyl<br>isobutanoate     | 27.977  | 28.047 | 3.95  | -    | -    | 2.47 | 3.11  | -            | -          | -    | -    | 3.08 | RI, MS |
| $\alpha$ -terpineole       | 31.003  | 31     | -     | 0.04 | -    | 0.03 | -     | -            | -          | 0.31 | 0.05 | 0.07 | RI, MS |
| Eugenol                    | 30.05   | 30.485 | 1.89  | 0.1  | -    | -    | 0.33  | -            | -          | 0.28 | 0.55 | -    | RI, MS |
| $\beta$ -caryophylle<br>ne | 32.156  | 32.298 | 0.59  | -    | -    | 0.25 | -     | -            | 0.04       | -    | -    | 0.78 | RI, MS |
| Isoeugenol                 | 33.067  | 33.04  | 1.68  | -    | -    | -    | -     | -            | -          | -    | -    | -    | RI, MS |
| Methyl<br>Isoeugenol       | 33.248  | 33.66  | 8.82  | 2.81 | 2.39 | 2.67 | -     | 2.76         | -          | 6.7  | 5.4  | -    | RI, MS |



|    |                   |  |       |        |      |       |       |        |        |      |        |      |      |        |        |        |       |      |      |   |  |
|----|-------------------|--|-------|--------|------|-------|-------|--------|--------|------|--------|------|------|--------|--------|--------|-------|------|------|---|--|
| 13 | â-terpineole      |  | 0.00  | 0.612  | 0.00 | 0.102 | 0.102 | 0.00   | 0.00   | 0.00 | 0.00   | 0.00 | 0.00 | 0.00   | 1      |        |       |      |      |   |  |
| 14 | Eugenol           |  | 0.272 | 0.408  | 0.00 | 0.408 | 0.408 | 0.408* | 0.534  | 0.00 | 0.534* | 0.00 | 0.00 | 0.408  | 0.250  | 1      |       |      |      |   |  |
| 15 | â-caryophyllene   |  | 0.509 | 0.00   | 0.00 | 0.00  | 0.00  | 0.218  | 0.047  | 0.00 | 0.047  | 0.00 | 0.00 | 0.654* | 0.089* | 1      |       |      |      |   |  |
| 16 | Isoeugenol        |  | 0.00  | 0.00   | 0.00 | 0.375 | 0.375 | 0.375  | 0.763  | 0.50 | 0.763  | 0.00 | 0.00 | 0.50   | 0.148* | 0.218  | 1     |      |      |   |  |
| 17 | Methyl Isoeugenol |  | 0.272 | 0.00   | 0.00 | 0.00  | 0.00  | 0.00   | 0.00   | 0.00 | 0.00   | 0.00 | 0.00 | 0.00   | 0.034  | 0.066  | 1     |      |      |   |  |
| 18 | Farnesol          |  | 0.272 | 0.408* | 0.00 | 0.00  | 0.00  | 0.408  | 0.089  | 0.00 | 0.089  | 0.00 | 0.00 | 0.408  | 0.253  | 0.0534 | 0.066 | 1    |      |   |  |
| 19 | Benzyl benzoate   |  | 0.272 | 0.408* | 0.00 | 0.00  | 0.00  | 0.408* | 0.089  | 0.00 | 0.089  | 0.00 | 0.00 | 0.408  | 0.253  | 0.0534 | 0.066 | 1    | 1    |   |  |
| 20 | Benzyl Salicylate |  | 0.00  | 0.00   | 0.60 | 0.50  | 0.50  | 0.50   | 0.654* | 0.60 | 0.654* | 0.00 | 0.00 | 0.20   | 0.00   | 0.00   | 0.00  | 0.00 | 0.00 | 1 |  |
|    |                   |  |       |        |      |       |       |        |        |      |        |      |      |        |        |        |       |      |      |   |  |

Notes: \*Significant at the 5% probability level

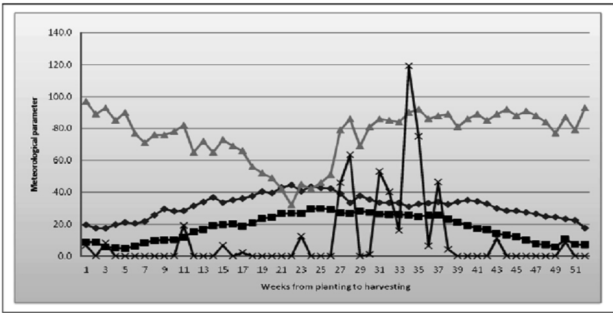
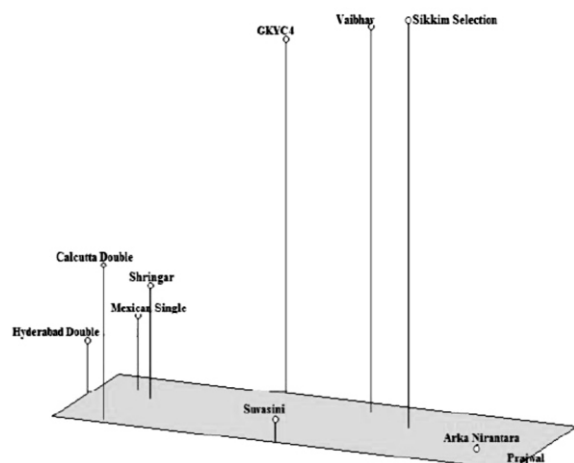
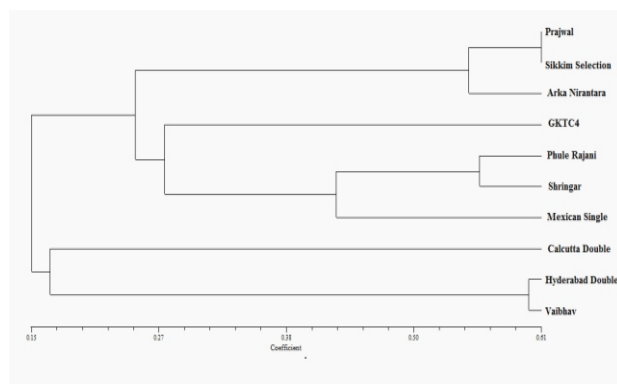
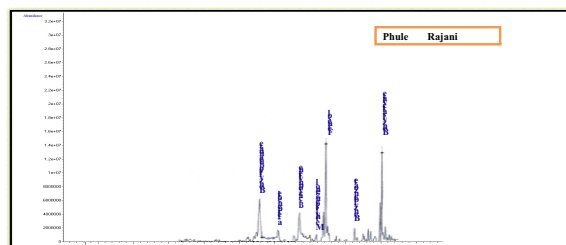
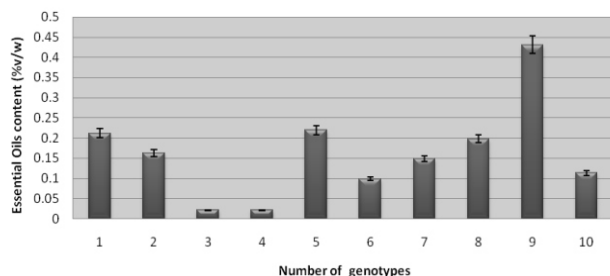


Figure 4.1. Meteorological data during the experimental period.



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## FORMULATION OF HIGH FIBER PUMPKIN COOKIES

**Anurag\*, Amar P. Garg and Shikha Sharma**

Research Scholar, Department of School of biological Engineering & Life Sciences,  
Shobhit Institute of Engineering & Technology, Deemed to be University, Meerut

\*Corresponding Author E-mail– [anurag43\\_@ymail.com](mailto:anurag43_@ymail.com)

### ABSTRACT

Numerous ways that or ideas of gathering the employment of accessible native food square measure more and more pursued however info on the nutrient worth of such native foodstuffs is crucial to encourage consumption to eradicate deficiency disease. the study aimed to include pumpkin flour which is usually disliked by style to supply High Fiber Pumpkin Cookies. Pumpkin was processed into raw flour. practical food specifically cookies were developed by supplementing pumpkin flour. associate organoleptic analysis was done by a panel of ten judges. Cookies are supplemented with five, 10, 20, and half-hour pumpkin flour. wet content was higher up to speed cookies i.e., 2.3%, protein, and fat content were most in T4 sample cookies supplemented with pumpkin flour i.e., 9.20% and 23.17%, fiber and ash content of T4 sample cookies supplemented with pumpkin flour was higher i.e., 3.59 and 2.42%. They formulate “High Fiber Pumpkin Cookies” to reinforce their nutritionary properties by incorporating dry pumpkin flour and to assess their chemical science properties in varied ratios with high periods at temperature. it was found that the pumpkin flour is often mixed with refined flour up to 10-30% to get a tasteful and alimentary cookie however two-hundredth pumpkin flour with eightieth refined flour gave the simplest results. The indulgent scale rating of the merchandise was found to be likable significantly by the panel of judges.

**Keywords:** Cookies, practical food, nutrient worth, organoleptic analysis, pumpkin flour

### INTRODUCTION

The terms cookies and crackers are almost synonymously used in India for the products prepared commercially using refined flour, hydrogenated fats, and sugar along with emulsifiers and other additives (21). However, in the western world ‘cookies’ are small round bread leavened with baking powder or soda and are small, flat-baked treats, holding milk, flour, eggs, sugar, and leavening agents. ‘Cracker’ is a thin crisp wafer made of flour and water with or without leavening and shortening agents either unsweetened or

semisweet (23). However, in this project the term cookie has been used throughout for the flat baked treat, holding flour, sugar, leavening agents, and milk solids in the form of curds.

There is a growing awareness amongst the consumers about the constituents that affect human health both positively and negatively. The number of such health-conscious consumers is fast increasing and so is the healthy food industry, Consumer purchase behavior for food is significantly changing across the world and consumers are becoming

increasingly conscious of the health-enhancing properties of food. With growing incidences of problems like obesity, diabetes, coronary heart diseases, and foodborne diseases, consumers are becoming aware of the role of food in ensuring health and well-being. There have been significant structural changes in the health and wellness food market compositions and India has a huge market potential for health and wellness food products with a market size of \$. 435 billion in 2013 and growing at a significantly high annual growth rate of about 13.8 percent from 2002-to 2013. HHI results indicate that there is significant competition in the health and wellness food market with an average HHI of 0.19. However, the structure of market competition shows a varied trend across the types, categories, prime-positioning, and distribution channels of health and wellness food products (2). The current COVID situation has taught us a lot and one of the main things which a lot of Indians learned fast, during the 70-day lockdown was adopting the habit of eating healthy food. During the lockdown, restaurants and other food outlets were closed, and a mass of the population gave up the idea of eating/ordering junk food and focused more on healthier meals. Consumers today are looking for: Healthy food options, Nutritional insights, Special dietary needs, Organic/natural/local, and Free-from foods. According to a study by Nielsen's Global Ingredient and Dining-Out Trends, as many as 64% of people globally are opting for a more organic diet, thanks to concerns over lifestyle diseases. Concerns over obesity, diabetes, high cholesterol, and high blood pressure could be leading 64% of global consumers to adopt diets that limit or exclude the consumption of certain foods or ingredients, says a new study. The data comes from Nielsen's Global Ingredient and Dining-Out Trends report, which surveyed

more than 30,000 online consumers in 63 countries. According to the latest report, which polled more than 30,000 consumers in 63 countries, almost two-thirds (64%) of respondents reported following a diet limiting or excluding some foods or ingredients. Such diets are most popular in Africa and the Middle East (84%) and Asia-Pacific (72%), notably due to cultural and religious reasons. 19% of those polled in the Asia-Pacific region follow a vegetarian diet, while 48% of Middle Eastern respondents follow a halal diet.

New foods with new health claims are flooding the market to meet the diverse demands of consumers (15) and there is ample scope to enhance the nutritional value of cookies both quantitatively and qualitatively using nutritious food ingredients. There are several food ingredients with exceptionally high nutritional values because of their nutraceutical and or nutritional components, such as millets, oilseeds, condiments, and other ingredients. Value addition to existing foods with such ingredients is a simple and feasible way of enhancing the nutritional value of foods and in turn the health benefits.

Most industries use refined flour, hydrogenated fat, sugar, and other additives to make cookies. It is well documented that most of the ingredients used in commercial cookies lack important nutrients. The refined flour lacks dietary fiber and micronutrients which are important health-promoting components (17). The hydrogenated fat includes trans-fats which have proven to be harmful to human health.

The pumpkin is a gourd-like squash of the genus *Cucurbita*, which belongs to the family Cucurbitaceae (which also includes gourds). It commonly refers to cultivars of any one of the species of *Cucurbita pepo*, *C. mixta*, *C. maxima*, and *C. moschata*, and is native to North America. Typically, it has a thick, orange, or yellow shell, creased from the stem to the bottom, containing the seeds and pulp.

Pumpkins are widely grown commercially and are used both in food and for recreation purposes. Pumpkin pie (16) for instance, is a traditional part of the “thanksgiving” meal in the United States and is often carved as decorations during Halloween (5). A pumpkin that has a little face carved in it and hollowed out and decorated with candles inside is known as a jack o’lantern; these are often used at Halloween, for example, to decorate windows.

Pumpkins (*Cucurbita moschatel* Duch,) are extensively grown in tropical and sub-tropical countries. In Thailand, it is one of the most widely cultivated vegetables. Pumpkins are traditionally consumed as freshly boiled and steamed or as processed food items such as soup and curry. Pumpkin is high in beta-carotene, which gives yellow or orange color. It has a pleasant yam-orange color (Most of the so-called yams you see in American grocery stores are orange-fleshed sweet potatoes), a major source of vitamin A . Consumption of foods holding carotene helps prevent skin diseases, eye disorders, and cancer (6). Incorporation of (3-carotene rich materials in the human diet, is, therefore, considered a cost-effective approach to vitamin-A related health problems (12).

Pumpkin is sweet, highly delicious, rich in flavor, cellulose, amino acid, calcium, phosphorus, zinc, carotene as well as a few good proteins and several minor elements, so it can strengthen the middle-jiao, to observe the clinical effects of the method for warming the middle-jiao and strengthening the spleen on gastric mucosa repair in chronic gastritis patients (14) and supplement qi deficiency translates loosely into a lack of energy (e.i. symptoms of qi deficiency in this system include) poor digestion, weakness, bloating, loose stools, low or no appetite anemia. Modern nutrition and medical science have proved that eating pumpkins can effectively prevent and the diseases like hypertension,

diabetes, adiposity, liver problems, atherosclerosis, and gastric ulcer. It also can accelerate cellular regeneration in the liver and kidney, prevent cancer and improve the immunological competence of the human body.

Pumpkin powder is a natural food-grade product created from pumpkin puree that has been dried and milled to a powder. It has been combined in the process with maltodextrin (derived from corn), cornflour, and lecithin to keep its free-flow characteristics. The usage of this product is extensive, for it can be directly taken after mixing with warm water, and it also can be used as a raw material, ingredient, and additive (2-5%) in food, beverage, cosmetics, and pharma industries to make high-quality and highly-nutritious functional foods and drugs including blood sugar reduction medicines, pumpkin liquids, pumpkin bread, pumpkin puddings, pumpkin steamed bread, pumpkin flaky pastry, pumpkin cakes, fine dried pumpkin noodles, pumpkin teas, sugar-free pumpkin jams, fast pumpkin nutritious powders.

## MATERIALS AND METHODS

Decent quality pumpkins, wheat flour, powdered sugar, vanilla essence, salt, baking powder, butter, and milk powder were obtained from the local market of Meerut. The fresh pumpkin without any black spots was scarce. Pumpkins were cut into 2×4 inches long pieces, peeled, and soaked in 0.2% citric acid solution for 10 min and drained off, the pumpkin residue was transferred to a stainless-steel tray and dried at 60 °C for 10 h. Spray-dried milk powder, to provide desired moisture content. Sugar was used as a sweetener which also plays a vital role in caramelization.

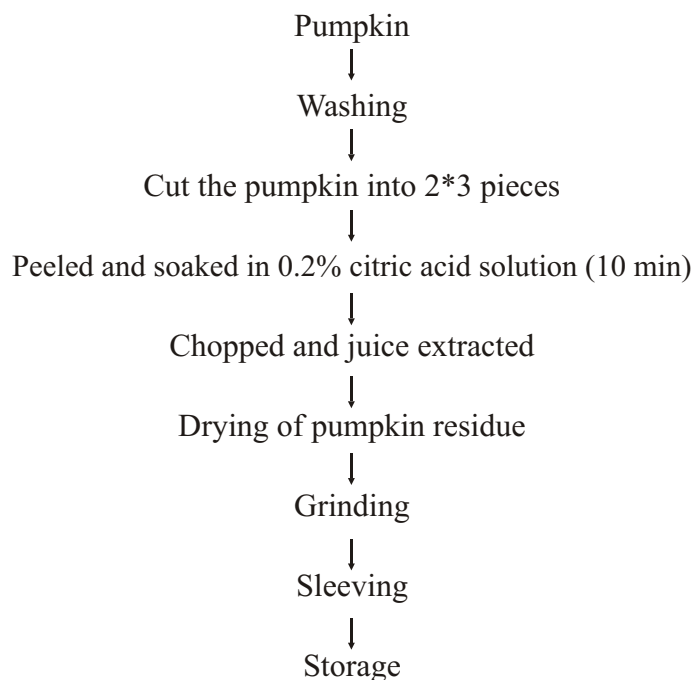


**Figure1:**Flow chart for pumpkin powder preparation.

Table1:Ingredients for pumpkin powder cookies

| Sample      | Pumpkin Powder | Refined flour |
|-------------|----------------|---------------|
| Sample (T0) | 0              | 100           |
| Sample (T1) | 5              | 95            |
| Sample (T2) | 10             | 90            |
| Sample (T3) | 20             | 80            |
| Sample (T4) | 30             | 70            |

## Preparation of Cookies

The proportion of ingredients in standardized formulas of cookies was given above pumpkin powder at 5, 10, 20, and 30 were incorporated in the standard formula for cookies with slight modification and standardized process. Pumpkin powder was mixed with half of the dough. Both the portion was rolled and placed over each other and rolled and rolled tightly. The rolled dough was chilled for 1 hour (sweet cookies) sheet of 3-5mm thick and round pieces of 0.8cm were cut and baked at 1500C-1650C for 20-25 minutes.

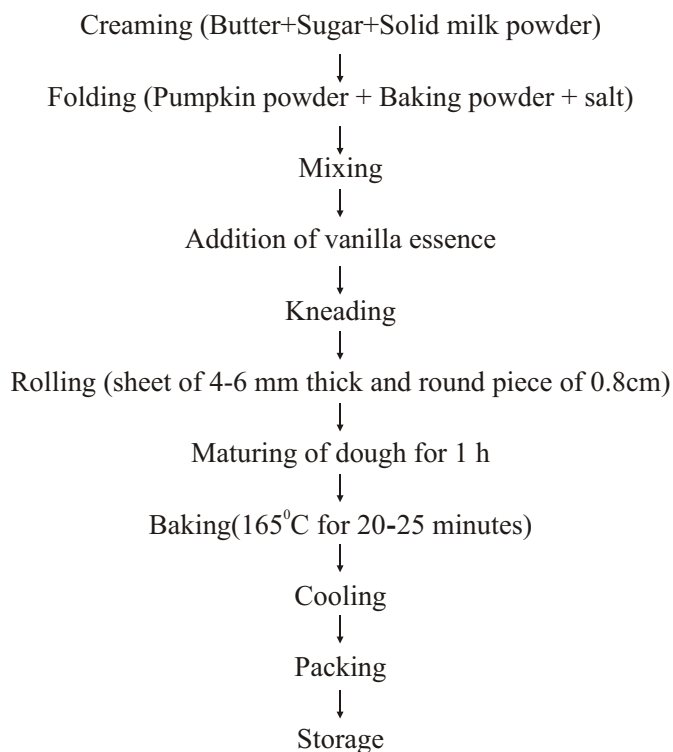


**Figure 2:** Flow chart for pumpkin powder cookies preparation.

## Modeling and Analysis

The high fiber pumpkin cookies formulation consists of refined flour, hydrogenated fat, sugar, and other additives. It is well documented that most of the ingredients used in commercial cookies lack important nutrients. The refined flour lacks dietary fiber and micronutrients that are important health-promoting components. Pumpkin powder is a natural food-grade product created from cookies puree that has been dried and milled to a powder and the ingredients used for cookies production are shown in table 2

**Table2.Common in gredients of cookies**

| Ingredients                    | Quantity |
|--------------------------------|----------|
| Refined flour or blend (maida) | 100g     |
| Sugar grounded                 | 50g      |
| Salt                           | 0.9g     |
| Sodium bicarbonate             | 1g       |
| Butter                         | 40g      |

|                  |          |
|------------------|----------|
| Vanilla          | 0.030g   |
| Water            | 10–12 ml |
| Baking powder    | 0.4g     |
| Skim Milk powder | 5g       |

The proportion of ingredients in standardized cookies is given above wherein pumpkin powder at 5, 10, 20, and 30 g was incorporated with slight modification and standardized process in 4 different percent of pumpkin flour, A (pumpkin flour- 5% Maida- 95%), B (pumpkin flour- 10% Maida- 90%), C (pumpkin flour- 20% Maida- 80%), D (pumpkin flour- 30% Maida- 70%). Both the portion was rolled and placed over each other and rolled and rolled tightly. The rolled dough was chilled for 1 hour (sweet cookies) sheet of 4-6 mm thick and round pieces of 0.8cm were cut and baked at 165°C for 25-30 minutes.

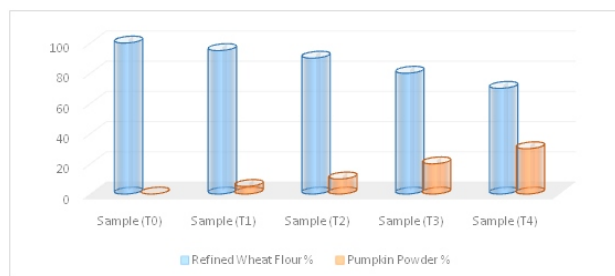


**Figure 3:** Percent ingredients of refined wheat flour (maida) and pumpkin powder for making high fiber pumpkin cookies.

## Proximate Analysis of Cookies

The proximate composition of samples like moisture content, ash content, crude protein, crude fat, and crude fiber was analyzed on a dry weight basis according to the American Association of Cereal Chemists (2000).

The present paper deals with the finding of the study, the effect on physio-chemical characteristics of pumpkin cookies, the cookies were developed from four different ratios with pumpkin flour.

## Moisture content

The moisture content will figure out by drying and weighted the sample about 5 grams into a hot air oven at  $70 \pm 2^\circ \text{C}$  for 3-4 hours and

cooling in a desiccator. The process of heating and cooling will repeat till the constant weight is achieved. The effect of storage period and different proportions of pumpkin flour and refined flour on the moisture content of pumpkin cookies, the moisture content of pumpkin cookies decreases considerably with the increases in storage period which results in Harding of cookies eventually with an increase in the storage period, however, decrease in moisture content of pumpkin cookies stored at room temperature. Moisture content significantly affected cookie firming. The higher moisture, the slower the firming rate and the lower the final firmness.

## Ash content

Weighted 5 grams of sample into a crucible. It will be subject to heating on low flame until the material will be completely charmed. It will follow by heating in a muffle furnace for about 3-5 hours at about  $600^\circ \text{C}$ , and then cool in a desiccator and weighed the percent ash will be calculated using the formula under (Ranganna, S 2007). Pumpkin flour is a good source of minerals like magnesium and phosphorous, in the present study, the storage period slightly increased the ash content of the cookies with an increase in storage period, probably because of a decrease in the moisture content of the cookies. The storage temperature had no significant effect on ash content.

## Fat content

The fat content will determine by the Soxhlet apparatus in which a 5-gm sample will be put into a thimble. the process will continue using petroleum ether or extraction at  $40-60^\circ \text{C}$  for 16 hours until the extraction will have been completed. Then bottom flask will remove, the excess volatile solvent distilled off and the residual fat will dry at  $80^\circ \text{C}$  in a hot air oven for 1 hour. Then flask will cool in desiccators and fat extract will obtain as crude fat. On the critical evaluation, the fat content of the pumpkin cookies was considerably increased

as the proportion of pumpkin flour is incorporated. The fat content of pumpkin cookies decreases considerably with the increase in storage period. Furthermore, the room temperature storage condition was found better as compared to ambient storage.

### Crude Fiber Content

The crude fiber content in pumpkin cookies was figured out by sequential acid and alkali hydrolysis method using the **Fibra-Plus apparatus**. A food sample of 2 g was taken in a crucible (W). The sample was boiled in 1.25% sulphuric acid and later boiled in 1.25% sodium hydroxide solution. The sample was dried in a hot air oven at 100°C till all the moisture was evaporated. The weight of the crucible before ashing was noted down (W<sub>1</sub>). The obtained dried sample was ashed in a muffle furnace at 550°C for 4 h. After ashing, the crucibles were cooled in a desiccator and weighed (W<sub>2</sub>). The residue obtained after subtraction of the ash was regarded as fiber.

The crude fiber was obtained by using the following equation.

$$\text{Crude Fiber \%} = \frac{W_1 - W_2}{W} \times 100$$

were, W<sub>1</sub> = Weight of the sample before ashing, g

W<sub>2</sub> = Weight of the sample after ashing, g

W = Weight of the sample, g

### Crude Protein

The crude protein in pumpkin cookies was found using the Micro-Kjeldahl distillation unit.

### Procedure

A finely grounded 0.8 g of food sample powder was transferred to a digestion tube, Add 0.5 g of digestion mixture and 12 ml of concentrated H<sub>2</sub>SO<sub>4</sub>. The sample was digested in a digestion unit till it became colorless. Then the digestion tubes were cooled and transferred to the distillation unit. 30 ml of 40% NaOH solution was allowed into the tube. Liberated ammonium gas was absorbed in a 4% boric acid solution having a

mixed indicator. The pink color of the boric acid solution was turned green, and this was titrated against 0.01N HCl until the pink color was obtained. The crude protein in percent was obtained by using the following formula.

$$\text{Protein (\%)} = \frac{\text{TV} \times 0.014 \times 100 \text{ (ml)} \times 0.01 \times 100}{6.25}$$

Weight of the sample (g) \* Aliquot used for distillation (ml)

were, TV = Titre Value

## RESULTS AND DISCUSSION

The present paper deals with the incorporation of pumpkin powder along with refined wheat flour to improve the nutritional quality of cookies. The main purpose of using pumpkin powder is to enhance the nutritive value of cookies and to study their acceptability in bakery products by consumers. The cookie prepared from pumpkin powder is a complete package of nutrition. To evaluate the quality and acceptability of pumpkin powder cookies, the chemical analysis as well as the organoleptic evaluation was followed in the present investigation. In this study, we took four samples T<sub>0</sub>, as the control in which only wheat flour was used while in the other four samples named T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> pumpkin powder was added as 5, 10, 20, and 30, respectively.

### Physico-Chemical Analysis of Pumpkin Powder Cookies

Different physical characteristics of cookies such as spread ratio, volume, and density are commonly studied. In the case of pumpkin cookies spread ratio, volume, and density was calculated including sample T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> and control sample (T<sub>0</sub>) using AACC (2000) protocol. The physical characteristics of cookies are prepared by replacing wheat flour with Pumpkin Flour incorporation (0-30%) in all refined purpose flour to develop dietary fiber-rich & nutritive cookies and its effect on Physico-

chemical properties, and sensory characteristics of cookies.

Physico-chemical parameters such as moisture, fat, protein, total ash, crude fiber, and the as content showed as light increase along with the increase in storage time. The ash content ranged from 0.46 % to 0.32 % (18). The moisture content of the cookies sample packed in HDPE decreased with the increase in the storage period. The decrease was more prominent when samples were stored at ambient temperature rather than being stored at room temperature. The moisture content ranged from 37.6 % to 44.18 % (AOAC, 1984). The fat content was found maximum in the sample (T<sub>2</sub>) (Pumpkin flour 10%, maida 90%) i.e., 2.9%, and minimum in the controlled sample i.e., 1.6%. The fiber content was least in the controlled sample i.e., 2.7% but was increased by incorporating pumpkin flour. It was maximum in sample C (pumpkin flour 30%, maida 70%) i.e., 7.3%. when judged on physicochemical properties, incorporation of pumpkin flour (10-30%) shows favorable results. ANOVA showed a significant result for all the Physico-chemical characteristics.

Sensory attributes such as color, aroma, taste, and overall acceptability were correlated among different pumpkin powder incorporated samples. Sample B (pumpkin flour 20%, maida 80%) is highly acceptable in taste, color, texture, overall acceptability as compared to other samples due to the reason that it does not has a slightly dark flavor due to the low level of pumpkin flour as well as a high level of refined flour makes it more palatable. ANOVA shows significant results for all the sensory characteristics. The microbiological test (yeast & mold count), conducted to estimate the shelf life of the cookie samples, showed that the samples if

kept at ambient temperature were safe for consumption for 5 days, but we can prolong their shelf life to 6 days by keeping it at room temperature.

**Table 3. Effect of different treatments on chemical analysis of pumpkin powder cookies.**

| Treatment      | Ash(%) | Moisture (%) | Fiber (%) | Fat (%) | Protein (%) |
|----------------|--------|--------------|-----------|---------|-------------|
| T <sub>0</sub> | 1.19   | 2.3          | 0.69      | 22.70   | 8.11        |
| T <sub>1</sub> | 1.30   | 1.98         | 1.19      | 22.72   | 8.38        |
| T <sub>2</sub> | 2.35   | 1.96         | 1.90      | 22.87   | 8.59        |
| T <sub>3</sub> | 2.40   | 1.99         | 2.42      | 22.89   | 8.72        |
| T <sub>4</sub> | 2.42   | 2.29         | 3.59      | 23.17   | 9.20        |

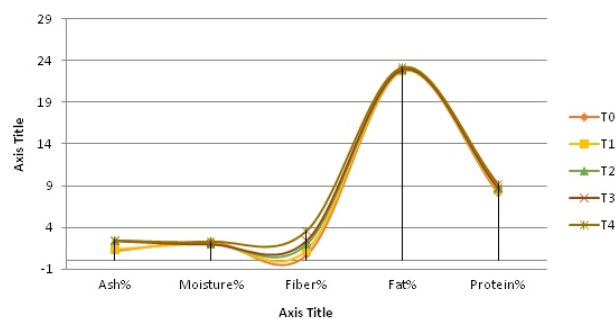


**Figure 4. Effect of different treatments on chemical analysis of pumpkin powder cookies.**

### Sensory Attributes of Pumpkin Cookies as Influenced By Storage Period, and Different Proportions of Pumpkin Flour and Refined Flour

Sensory attributes as influenced by storage period, and different proportions of pumpkin flour, and maida packed in LDPE were evaluated for fresh condition and at 2 days intervals up to 6 days of ambient storage & room temperature storage. The nine-point hedonic rating test method was used for the evaluation of different samples of pumpkin cookies. Different attributes are color, taste, texture, and overall acceptability.

**Table4: Effect of ambients to rageaf ter 60 day son color, texture, taste, and over all accept ability of pumpkin cookies.**

| Treatment      | Color |      |      |      | Texture |     |     |     | Taste |     |     |     | Overallacceptability |     |     |     |
|----------------|-------|------|------|------|---------|-----|-----|-----|-------|-----|-----|-----|----------------------|-----|-----|-----|
| Days           | 15    | 30   | 45   | 60   | 15      | 30  | 45  | 60  | 15    | 30  | 45  | 60  | 15                   | 30  | 45  | 60  |
| T <sub>0</sub> | 6.0   | 5.5  | 5.4  | 5.0  | 5.2     | 5.1 | 5   | 5   | 5.6   | 5.2 | 5.1 | 5   | 6                    | 5.2 | 5   | 5   |
| T <sub>1</sub> | 7.80  | 7.20 | 7.0  | 6.6  | 7.3     | 6.6 | 6.8 | 6.2 | 7.3   | 6.5 | 6.1 | 5   | 7.3                  | 6.5 | 6.1 | 5   |
| T <sub>2</sub> | 8.40  | 8.20 | 8.1  | 8.0  | 8.3     | 7.8 | 7.6 | 7.4 | 8.3   | 7.8 | 7.6 | 7   | 8.3                  | 7.8 | 7.6 | 7   |
| T <sub>3</sub> | 8.30  | 8.0  | 8.0  | 7.8  | 8.3     | 7.8 | 7.4 | 7.2 | 8.3   | 7.4 | 7   | 6.8 | 8.3                  | 7.4 | 7   | 6.8 |
| T <sub>4</sub> | 8.0   | 7.60 | 7.50 | 7.20 | 8       | 7.9 | 7.6 | 7.2 | 8     | 7.6 | 7.2 | 7   | 8                    | 7.6 | 7.2 | 7   |

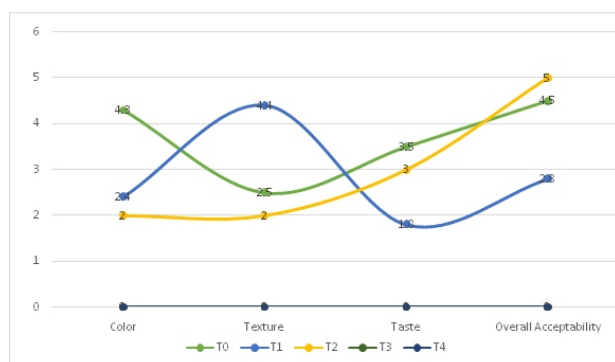


Figure 5: Effect of ambient storage after 60 days on color, texture, taste, and overall acceptability of pumpkin cookies.

Pumpkin flour incorporation (0-30%) in all refined purpose flour to develop dietary fiber-rich & nutritive cookies and its effect on physicochemical properties, and sensory characteristics of cookies, the physicochemical parameters such as moisture, fat, protein, ash, crude fiber. The microbiological test (yeast & mold count) was conducted to estimate the shelf life of the cookie's samples, the samples, if kept at ambient temperatures, were a shelf life of 2 months.

## CONCLUSION

The studies were conducted for entitled development of pumpkin cookies and sensory after storage. The five treatments were conducted i.e., sample (100: 00, 95: 5, 90:10, 80: 20, 70: 30) the sample two was found satisfactory after analysis and sensory, pumpkin cookies were found 2 months of shelf life at ambient temperature and Different sensory attributes like color, flavor, taste,

texture and overall acceptability were preformed during shelf-life study sample 80: 20 and sample 70: 30 was found significant difference their taste, flavor, color change to store for a period of up to 60 days.

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## TO ESTIMATE THE MAGNITUDE OF HETEROSIS FOR FRUIT YIELD AND QUALITY CONTRIBUTING CHARACTERS IN BRINJAL (*SOLANUM MELONGENA* L.)

Ashish Kumar\*, Shardulya Shukla, Jagraj Singh, Mohit and Vipin Kumar

College of Horticulture, SVP University of Agriculture and Technology, Meerut

\*Corresponding Author E-mail– [dr.ashishkumardangi@gmail.com](mailto:dr.ashishkumardangi@gmail.com)

### INTRODUCTION

Brinjal (*Solanum melongena* L.) is an third most important vegetable crop in India. Brinjal or aubergine, is a species of nightshade, grown for its edible fruit. Brinjal is the common name in North America, Australia New Zealand, but British English uses the French word aubergine. It's belong to the family Solanaceae and having  $2n = 24$  chromosome number. The family contains more than 2000 species distributed in 75 genera. In the genus "Solanum" there are three main species viz; esculantum (large round), serpentium (long slender) and depressum (dwarf brinjal) (3). It originated in India as Subcontinent people are used to grow brinjal since last 4000 years (5). In India it is one of the most common, popular and principal vegetable crops grown throughout the country except higher altitudes. It is a perennial but grown commercially as an annual crop. A large number of cultivars are grown in India consumer preference being dependent upon fruit color, size and shape. The fruit is widely used in cooking for table purpose. The wonderful nutritional value and health benefits of brinjal are primarily derived from its vitamin, mineral, and nutrient content. Brinjal are a rich source of vitamin C, vitamin K, vitamin B<sub>6</sub>, thiamin, niacin, magnesium, phosphorous, copper, dietary fiber, folic acid,

potassium, and manganese. Brinjal is a non-starchy vegetable, which is low in calories and carbohydrates. Foods that have a low glycemic index don't raise blood sugars as quickly as other foods that contain carbohydrate. The nutritional value per 100 g of brinjal fruit contains 92.70 per cent moisture, 0.1 g fat, 5.7 g carbohydrate and 1.0 g protein. In addition, numerous vitamins and minerals, such as B1, B6, folic acid, copper, manganese (0.25 mg), magnesium (14 mg), potassium (230 mg) and about 10 per cent of the daily value of fiber are also present (USDA Nutrient Database, 2005). It's contains a higher content of free reducing sugars, anthocyanin, phenols, glycol alkaloids (solasodine) and amide proteins. Bitterness in brinjal fruit is due to the presence of saponins and glycol alkaloids (6). Brinjal is an excellent source of dietary fibre. Brinjal are rich in antioxidants, specifically nasunin found in brinjal skin which gives it its purple colour is a potent antioxidant and free radical SCAvenger that has been shown to protect cell membranes from damage. Nasunin helps eliminate the buildup of plaque in the blood vessels, keeping your heart and the cardiovascular system healthy. Brinjal is a great food to help you lose weight. Brinjal is a low-carb, nutrient-dense, calorie-poor food, meaning that it contains high levels of

nutrients but not a lot of calories or carbohydrates. One cup of brinjal contains only eight grams of carbohydrates, two of those coming from fiber. They are also known to have alkaloid solanine in roots and leaves. Some medicinal uses of brinjal include treatment of diabetes, asthma, cholera, bronchitis and dysuria. Fruits and leaves are administered to lower blood cholesterol levels. Brinjals are enriched with menstruation-inducing properties. Due to these properties, brinjals may also lead to abortion. These are also not good as they may cause acidity problems, therefore it is suggested that women should avoid eating brinjal during pregnancy. Brinjal on its own is a nutritious food, however, and can supply key vitamins and minerals to your diet. Recent production data has revealed that India. Ranks second in brinjal production contributing 25.48 per cent of the total global production with a cultivated area of 7,27,000 ha, production of 1,23,23,000 MT and 16.95 MT/ha productivity (7). The brinjal is usually self-pollinated vegetable crop. However, it has been reported that the extent of often cross-pollination can range from 2% to as high as 48%. Brinjal continues to be a choice of breeders for exploitation of hybrids to hardy nature of crop, comparatively large size of flowers and more number of seeds in a single fruit. The phenomenon of heterosis of  $F_1$  hybrids can also reflect specific combining ability (SCA) and general combining ability (GCA) of parental lines. The combining ability works as the basic tool for improved production of crops in the form of  $F_1$  hybrids (5). Heterosis studies can also provide the basis for exploitation of valuable hybrid combinations and their commercial utilization in future breeding programs (3).

## **MATERIALS AND METHODS**

### **Experimental site**

Field experiment of the present investigation was carried out at Horticulture Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut. Field plot was well prepared for conducting of the experimental material comprising of entries 36 (8 parents and 28  $F_1$ s). These entries were evaluated in a Randomized Block Design with three replications during kharif Season 2017-2018. Seeds of the each parental lines and crosses were sown by hand in Protrayes at H.R.C. The length of row was 3m by maintaining distance of 1.2m row to row and 60cm plant to plant distance. All the recommended agronomic inputs and practices were applied to the crop during the season for raising good crop.

### **Experimental Material**

The experimental material comprised of eight brinjal genotypes namely, K.S-331, DBL-24, A. Abhilomb, A. Parthibha, J.B.-6, F.Collection-2, J.B.L.-03-04, Assury. These genotypes were collected from IIVR Varanasi used for crossing programme in a half diallel crosses.

### **Generation of material**

Parental lines were grown during *kharif* 2017-2018 and all possible cross combinations were made in half diallel fashion to produce 28  $F_1$  (Table 1). Crossing was accomplished by removing the anther from the female parent (emasculature) and by transferring the pollen grain from the desired parent. After removing the anther carefully and covered with butter paper bag. On the next day, mature anthers of the pollen parent were used for crossing. After crossing the stigma were again covered with butter paper bag. At maturity, fruit were harvested and seeds collected and were kept in envelopes of individual cross combinations for evaluating  $F_1$ -generation in the subsequent year.

**List of F<sub>1</sub> Crosses**

| S. No. | Crosses                    | S.No. | Crosses                       |
|--------|----------------------------|-------|-------------------------------|
| 1      | DBL-24 x K.S.-331          | 15    | J.B.-6 x A. Abhilomb          |
| 2      | A. Abhilomb x K.S.-331     | 16    | F.Collection-2 x A. Abhilomb  |
| 3      | A. Parthibha x K.S.-331    | 17    | J.B.L.03-04 x A. Abhilomb     |
| 4      | J.B.-6 x K.S.-331          | 18    | Assury x A. Abhilomb          |
| 5      | F.Collection-2 x K.S.-331  | 19    | J.B.-6 x A. Parthibha         |
| 6      | J.B.L.03-04 x K.S.-331     | 20    | F.Collection-2 x A. Parthibha |
| 7      | Assury x K.S.-331          | 21    | J.B.L.03-04 x A. Parthibha    |
| 8      | A. Abhilomb x DBL-24       | 22    | Assury x A. Parthibha         |
| 9      | A. Parthibha x DBL-24      | 23    | F.Collection-2 x J.B.-6       |
| 10     | J.B.-6 x DBL-24            | 24    | J.B.L.03-04 x J.B.-6          |
| 11     | F.Collection-2 x DBL-24    | 25    | Assury x J.B.-6               |
| 12     | J.B.L.03-04 x DBL-24       | 26    | J.B.L.03-04 x F.Collection-2  |
| 13     | Assury x DBL-24            | 27    | Assury x F.Collection-2       |
| 14     | A. Parthibha x A. Abhilomb | 28    | Assury x J.B.L03-04           |

**Recording of observations**

A total of five competitive plants per treatment in all the three replications were randomly tagged for recording the observations on the following twelve quantitative and qualitative characters. The procedure adopted in recording observations in different characters are as follows

**Plant height (cm)**

The plant height of main plant was measured in cm from base to tip of the growing point of the main shoot with the help of meter scale at the final harvest stage and the average plant height was calculated.

**Primary branches per plant**

Counting the number of primary branch of the selected plants and average was calculated.

**Plant spread (cm)**

At final harvesting the maximum horizontal spread of selected plants were recorded in East to West and North to South

direction by using meter scale and averaged them to find out plant spread.

**Days to first flowering**

Data was taken as days from the date of transplant to till first flowering was recording on the individual plant basis and average was calculated.

**Days to first fruit set**

The data on which 50% of the plants showed first fruit set was recorded and the number of days taken from date of transplanting and average calculated.

**Days to first fruit picking**

The number of days taken for first fruit picking was also calculated from the date of transplanting in each treatment on individual plant basis.

**Average fruit weight (g)**

The average fruit weight was obtained by dividing the total yield of plant by total number of fruits picked from a plant in each treatment.

**Fruit length (cm)**

The length of fruits was measured by using a meter scale of five randomly selected fruits and the average fruit length was calculated.

**Fruit diameter (cm)**

The diameter of fruits was measured by using a vernier caliper and meter scale of five randomly selected fruits and the average fruit length was calculated.

**Fruit index (cm)**

The fruit index calculating by multiplying average fruit length with average fruit diameter.

**Fruits per plant**

The total numbers of fruits picked from five randomly selected plants was recorded. The average numbers of fruits per plant was derived by dividing the total no of fruits by five plants in each treatment.

## Yield per plant (g)

The total weight of fruits picked from five randomly selected plants was recorded. The average yield per plant was derived by dividing the total weight of fruits by five plants in each treatment.

## Statistical analysis

In the present investigation, diallel mating design was followed and the replication wise mean values of the treatments for twelve characters were subjected to the following statistical analysis.

## Estimation of heterosis

The magnitude of heterosis over better parents was calculated with the help of the formulae given below:

$$(i) \text{ Heterosis over better parent (\%)} = \frac{\bar{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

Where,

BP = the value of the better parent.

(ii) Heterosis over mid parent (%)

$$= \frac{\bar{F}_1 - \overline{MP}}{\overline{MP}} \times 100$$

MP = the value of the mid parent.

## Test of significance

Significance of heterosis better parents was tested by the method suggested by (10).

$$\text{S.E. of difference between any two values (BP)} = \sqrt{2VE/r}$$

Where,

VE = error variance

r = number of replications

C. D. = S.E. x t

# RESULTS AND DISCUSSION

## Estimation of heterosis

Increase and decrease in the performance of F<sub>1</sub> over better parent and mid parent in respect of all the characters under study are presented in Table 3.1 and the results are presented as under

**Table 3.1 Estimates of Heterosis (%) over better and mid parent for twelve characters in brinjal (*Solanum melongena* L.)**

|    | Hybrids                   | Plant height |          | Primary branches /plant |        | Plant spread |          | Days to first flowering |          | Days to first fruit set |          | Days to first fruit picking |          |
|----|---------------------------|--------------|----------|-------------------------|--------|--------------|----------|-------------------------|----------|-------------------------|----------|-----------------------------|----------|
|    |                           | BP           | MP       | BP                      | MP     | BP           | MP       | BP                      | MP       | BP                      | MP       | BP                          | MP       |
| 1  | DBL-24 x K.S.-331         | 27.72*       | 31.70*   | 29.52*                  | 37.37* | 7.92**       | 15.49*   | -1.53*                  | -3.07*   | -1.53*                  | -3.01*   | -2.65*                      | -4.03*   |
| 2  | A. Abhilomb x K.S.-331    | -5.19*       | -1.65*   | -6.50*                  | 0.88   | -3.57*       | 7.45**   | 7.94**                  | 2.86**   | 8.12**                  | 3.16**   | 11.08*                      | 4.17**   |
| 3  | A. Parthibha x K.S.-331   | 19.39*       | 25.29*   | -9.15*                  | 10.78* | 9.37**       | 22.39*   | 1.42*                   | -5.69*   | 1.13                    | -5.74*   | 0.74                        | -6.08*   |
| 4  | J.B.-6 x K.S.-331         | 7.76**       | 16.72*   | 36.07*                  | 46.26* | 48.22*       | 61.43*   | 4.20**                  | 2.29**   | 4.75**                  | 2.71**   | 1.75**                      | 0.92     |
| 5  | F.Collection-2 x K.S.-331 | 10.33*       | 17.23*   | 27.62*                  | 48.89* | -1.05        | 8.00**   | -10.82**                | -13.78** | -10.03**                | -13.01** | -10.84**                    | -13.97** |
| 6  | J.B.L.-03-04 x K.S.-331   | 27.41*       | 28.93*   | -2.34*                  | 7.30** | 11.37*       | 11.98*   | 2.80**                  | 1.32**   | 1.37*                   | 0.81     | 1.00                        | -0.49    |
| 7  | Assury x K.s.-331         | -19.09**     | -14.05** | 2.86**                  | 22.73* | 26.44*       | 37.30*   | -10.51**                | -10.91** | -9.06*                  | -9.28*   | -10.16**                    | -10.40** |
| 8  | A. Abhilomb x DBL-24      | 6.31**       | 6.96**   | 56.91*                  | 78.70* | -15.31**     | -11.54** | 7.49**                  | 4.10**   | 7.44**                  | 4.13**   | 9.62**                      | 4.35**   |
| 9  | A. Parthibha x DBL-24     | 6.62**       | 8.57**   | -9.15*                  | 15.95* | -16.48**     | -12.36** | -0.44                   | -5.87*   | 0.57                    | -4.76*   | 0.49                        | -4.90*   |
| 10 | J.B.-6 x DBL-24           | 4.70**       | 16.63*   | 13.93*                  | 29.30* | -22.01**     | -9.67*   | -0.40                   | -0.66    | 0.90                    | 0.45     | -1.66*                      | -2.25*   |
| 11 | F.Collection-2 x DBL-24   | -8.15*       | -5.26*   | 64.52*                  | 82.14* | -7.11*       | -5.12*   | -5.49*                  | -7.15*   | -5.15*                  | -6.87*   | -4.84*                      | -6.83*   |

|    |                               |          |          |          |        |          |          |          |          |          |          |          |          |
|----|-------------------------------|----------|----------|----------|--------|----------|----------|----------|----------|----------|----------|----------|----------|
| 12 | J.B.L.-03-04 x DBL-24         | 27.71*   | 33.22*   | 3.13**   | 19.46* | -7.76*   | -0.80    | 0.80     | 0.66     | 1.27     | 0.32     | -1.00    | -1.05    |
| 13 | Assury DBL-24                 | 19.98*   | 31.19*   | 46.24*   | 65.85* | -20.28** | -7.91*   | 7.82**   | 6.62**   | 8.65**   | 7.29**   | 6.97**   | 5.74**   |
| 14 | A. Parthibha x A. Abhilomb    | 27.81*   | 29.35*   | 10.37*   | 26.13* | 13.04*   | 13.59*   | -20.41** | -22.25** | -20.08** | -21.85** | -18.84** | -19.29** |
| 15 | J.B.-6 x A. Abhilomb          | -12.37** | -1.84*   | 52.03*   | 52.65* | 4.19**   | 25.17*   | 1.84**   | -1.10*   | 3.25**   | 0.53     | 4.75**   | -0.92    |
| 16 | F.Collection-2 x A. Abhilomb  | 22.32*   | 25.40*   | 31.71*   | 63.64* | 10.44*   | 12.99*   | 16.53*   | 14.90*   | 17.32*   | 15.83*   | 19.24*   | 16.00*   |
| 17 | J.B.L.-03-04 x A. Abhilomb    | 15.01*   | 20.68*   | 16.41*   | 18.73* | -9.90*   | 0.88     | 0.71     | -2.60*   | 0.81     | -3.25*   | 4.51**   | -0.46    |
| 18 | Assury x A. Abhilomb          | -9.95*   | -1.00    | -10.57** | 13.40* | -28.45** | -14.27** | 9.18**   | 4.53**   | 9.88**   | 5.11**   | 10.23*   | 3.67**   |
| 19 | J.B.-6 x A. Parthibha         | -14.66** | -3.40*   | -14.63** | -2.10* | 5.13**   | 26.78*   | -3.85*   | -8.84*   | -2.97*   | -7.67*   | -4.06*   | -9.79*   |
| 20 | F.Collection-2 x A. Parthibha | 3.09**   | 4.44**   | 6.10**   | 45.61* | 28.76*   | 32.36*   | -0.15    | -3.85*   | -0.42    | -3.89*   | -1.11    | -4.35*   |
| 21 | J.B.L.-03-04 x A. Parthibha   | -22.76** | -18.02** | 12.20*   | 26.03* | -6.08*   | 5.61**   | 10.95*   | 4.75**   | 12.16*   | 5.17**   | 9.24**   | 3.44**   |
| 22 | Assury x A. Parthibha         | 12.56*   | 25.10*   | -10.37** | 25.11* | -1.44*   | 18.56*   | 2.66**   | -4.08*   | 2.12**   | -4.56*   | 1.35*    | -5.24*   |
| 23 | F.Collection-2 x J.B.-6       | -27.41** | -16.89** | 48.36*   | 83.76* | 17.60*   | 38.66*   | 7.28**   | 5.68**   | 6.20**   | 4.75**   | 4.61**   | 1.80**   |
| 24 | J.B.L.-03-04 x J.B.-6         | -9.05*   | -2.58*   | 24.22*   | 27.20* | 27.35*   | 38.01*   | 10.53*   | 10.09*   | 10.91*   | 9.37**   | 10.52*   | 9.79**   |
| 25 | Assury x J.B.-6               | 31.02*   | 33.76*   | -2.46*   | 23.32* | 37.41*   | 37.86*   | -23.87** | -24.92** | -22.85** | -24.16** | -23.06** | -23.48** |
| 26 | J.B.L.-03-04 x F.Collection-2 | 4.31**   | 12.07*   | 39.06*   | 75.37* | 15.38*   | 26.55*   | -0.82    | -2.70*   | -0.92    | -3.66*   | 0.58     | -1.47*   |
| 27 | Assury x F.Collection-2       | 9.41**   | 23.02*   | 52.00*   | 56.16* | -12.62** | 2.76**   | -3.57*   | -6.34*   | -4.22*   | -7.16*   | -4.04*   | -7.14*   |
| 28 | Assury J.B.L.-03-04           | 22.33*   | 28.49*   | 10.16*   | 41.71* | 22.81*   | 32.69*   | 7.28**   | 6.22**   | 4.74**   | 4.42**   | 6.09**   | 4.81**   |
|    | SE (sij)                      | 0.73     | 0.65     | 0.51     | 0.44   | 0.58     | 0.50     | 0.61     | 0.51     | 0.66     | 0.58     | 0.62     | 0.53     |
|    | CD AT 5%                      | 1.46     | 1.30     | 1.02     | 0.88   | 1.16     | 1.00     | 1.22     | 1.02     | 1.32     | 1.16     | 1.24     | 1.06     |

\*,\*\* significant at 5% and 1% level of significance respectively.

Conti.....

|   | Hybrids                   | Average per fruit wt. |        | Length of fruit |          | Diameter of fruit |          | Fruit index |          | Number of fruit /plant |          | Yield of fruit /plant |        |
|---|---------------------------|-----------------------|--------|-----------------|----------|-------------------|----------|-------------|----------|------------------------|----------|-----------------------|--------|
|   |                           | BP                    | MP     | BP              | MP       | BP                | MP       | BP          | MP       | BP                     | MP       | BP                    | MP     |
| 1 | DBL-24 x K.S.-331         | -8.87*                | 9.27** | -17.85**        | 6.27**   | 0.36**            | 9.56**   | -17.86**    | 12.92*   | 1.93**                 | 7.32**   | 24.89*                | 34.54* |
| 2 | A. Abhilomb x K.S.-331    | -2.23*                | 13.47* | -4.81*          | 18.79*   | -22.45**          | 3.62**   | 22.43*      | 34.15*   | -4.72*                 | 3.26**   | 19.81                 | 33.33* |
| 3 | A. Parthibha x K.S.-331   | 17.31*                | 44.65* | -32.04**        | -17.86** | -29.63**          | -2.76*   | -26.92**    | -13.24** | -19.74**               | -18.16** | 3.31                  | 27.78* |
| 4 | J.B.-6 x K.S.-331         | -12.95**              | 3.69** | 2.64**          | 11.26*   | -12.06**          | 0.12     | -9.88       | 10.16*   | -38.34**               | -23.10** | -5.56                 | 1.50   |
| 5 | F.Collection-2 x K.S.-331 | -17.95**              | 11.17* | -33.33**        | -19.05** | -26.96**          | 4.64**   | -25.01**    | -6.97    | -16.31                 | 5.12**   | 20.74*                | 38.87* |
| 6 | J.B.L.-03-04 x K.S.-331   | -2.57*                | 3.63** | -2.89*          | 13.75*   | 21.00*            | 28.37*   | 17.19*      | 44.23*   | -17.48**               | -5.90*   | 8.42                  | 15.50  |
| 7 | Assury x K.s.-331         | 5.56**                | 18.51* | -6.89*          | 12.62*   | -29.21**          | -10.98** | 0.72        | 5.78     | -8.02*                 | -7.23*   | 8.84                  | 28.16  |

|           |                               |              |              |              |              |              |              |              |              |              |              |              |              |
|-----------|-------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| 8         | A. Abhilomb x DBL-24          | -7.87*<br>*  | 24.24*<br>*  | 26.49*<br>*  | 32.72*<br>*  | -28.01<br>** | 1.86**       | -9.10        | 32.18*<br>*  | 1.54**       | 15.35*<br>*  | 32.08*<br>*  | 56.97*<br>*  |
| 9         | A. Parthibha x DBL-24         | -27.52<br>** | 2.42**       | 27.40*<br>*  | 38.92*<br>*  | -37.89<br>** | -9.48*<br>*  | -20.84<br>** | 20.73*<br>*  | 14.67*<br>*  | 22.98*<br>*  | -3.35        | 26.47*<br>*  |
| 10        | J.B.-6 x DBL-24               | 14.59*<br>*  | 15.54*<br>*  | -30.67<br>** | -15.77<br>** | 6.46**       | 11.53*<br>*  | -18.51<br>** | -4.97        | -1.55*<br>*  | 17.83*<br>*  | 19.83        | 37.94*<br>*  |
| 11        | F.Collection-2 x DBL-24       | -35.13<br>** | -1.57        | -11.57<br>** | -4.08*<br>*  | -34.16<br>** | -0.95*<br>*  | -41.89<br>** | -9.08        | -15.06<br>** | 10.83*<br>*  | 2.26         | 25.25*<br>*  |
| 12        | J.B.L.-03-04 x DBL-24         | 9.71**       | 24.77*<br>*  | 29.45*<br>*  | 46.11*<br>*  | -18.06<br>** | -15.53<br>** | 5.94         | 22.66*<br>*  | 3.56**       | 12.68*<br>*  | 31.46*<br>*  | 50.10*<br>*  |
| 13        | Assury x DBL-24               | -21.94<br>** | 2.59**       | -6.20*<br>*  | 2.20**       | -18.96<br>** | 8.69**       | -24.21<br>** | 7.41         | -13.90<br>** | -10.08<br>** | -27.39<br>** | -9.15        |
| 14        | A. Parthibha x A. Abhilomb    | 34.81*<br>*  | 44.96*<br>*  | 3.81**       | 8.10**       | -8.91*<br>*  | -4.16*<br>*  | -5.30        | 3.51         | -7.14*<br>*  | -1.19*<br>*  | 25.93*<br>*  | 41.96*<br>*  |
| 15        | J.B.-6 x A. Abhilomb          | -26.06<br>** | -0.83        | 0.81         | 17.69*<br>*  | -8.41*<br>*  | 33.14*<br>*  | 29.46*<br>*  | 69.79*<br>*  | -30.31<br>** | -7.72*<br>*  | 6.02         | 10.09        |
| 16        | F.Collection-2 x A. Abhilomb  | -13.95<br>** | 3.78**       | 6.85**       | 10.65*<br>*  | 8.63**       | 20.90*<br>*  | 15.93*<br>*  | 33.13*<br>*  | -1.52*<br>*  | 15.82*<br>*  | 23.87*<br>*  | 28.56*<br>*  |
| 17        | J.B.L.-03-04 x A. Abhilomb    | 7.55**       | 31.42*<br>*  | -1.61*<br>*  | 6.25**       | -40.22<br>** | -16.95<br>** | -31.19<br>** | -9.21        | -27.18<br>** | -11.07<br>** | 22.88*<br>*  | 28.77*<br>*  |
| 18        | Assury x A. Abhilomb          | -32.69<br>** | -30.09<br>** | -3.68*<br>*  | 0.22         | -22.49<br>** | -15.82<br>** | -19.04<br>** | -15.34<br>** | -11.39<br>** | -3.23*<br>*  | -34.39<br>** | -30.07<br>** |
| 19        | J.B.-6 x A. Parthibha         | -10.85<br>** | 25.36*<br>*  | -14.38<br>** | -3.51*<br>*  | -29.11<br>** | 5.93**       | -21.59<br>** | 9.23         | -42.23<br>** | -26.89<br>** | -11.18       | 3.47         |
| 20        | F.Collection-2 x A. Parthibha | -2.84*<br>*  | 10.06*<br>*  | 16.96*<br>*  | 17.63*<br>*  | -10.01<br>** | -4.52*<br>*  | 6.20         | 12.16*<br>*  | -28.57<br>** | -11.60<br>** | -11.97       | -4.06        |
| 21        | J.B.L.-03-04 x A. Parthibha   | -4.91*<br>*  | 22.88*<br>*  | -9.59*<br>*  | -6.08*<br>*  | -19.02<br>** | 16.00*<br>*  | -20.93<br>** | 10.73*<br>*  | -33.66<br>** | -23.08<br>** | -17.81       | -3.49        |
| 22        | Assury x A. Parthibha         | 5.98**       | 18.02*<br>*  | 9.86**       | 9.95**       | -23.19<br>** | -12.62<br>** | -15.60<br>** | -3.93        | -24.05<br>** | -21.91<br>** | -10.02       | -4.44        |
| 23        | F.Collection-2 x J.B.-6       | -41.55<br>** | -11.66<br>** | 6.66**       | 20.79*<br>*  | -21.12<br>** | 21.39*<br>*  | 9.76         | 58.00*<br>*  | -36.27<br>** | -6.11*<br>*  | 11.06        | 19.52        |
| 24        | J.B.L.-03-04 x J.B.-6         | -9.90*<br>*  | 1.73*<br>*   | -26.49<br>** | -19.98<br>** | 83.50*<br>*  | 97.88*<br>*  | 58.44*<br>*  | 59.82*<br>*  | -21.24<br>** | -12.52<br>** | 8.70         | 9.74         |
| 25        | Assury x J.B.-6               | -8.14*<br>*  | 20.03*<br>*  | -29.77<br>** | -20.79<br>** | -16.39<br>** | 15.60*<br>*  | -23.96<br>** | -3.46        | -24.35<br>** | -6.26*<br>*  | 20.22*<br>*  | 32.72*<br>*  |
| 26        | J.B.L.-03-04 x F.Collection-2 | -8.29*<br>*  | 29.24*<br>*  | -2.53*<br>*  | 1.80**       | -28.63<br>** | 5.69**       | -24.03<br>** | 9.89         | -47.25<br>** | -27.07<br>** | 3.34         | 12.19        |
| spn um 27 | Assury x F.Collection-2       | -15.12<br>** | 5.48**       | -3.96*<br>*  | -3.49*<br>*  | -2.16*<br>*  | 17.12*<br>*  | -5.19        | 13.09*<br>*  | -18.99<br>** | 2.40**       | 13.64        | 16.82        |
| 28        | Assury x J.B.L.-03-04         | 3.28**       | 22.37*<br>*  | -20.07<br>** | -16.90<br>** | 33.42*<br>*  | 75.26*<br>*  | 15.44*<br>*  | 47.49*<br>*  | -31.07<br>** | -21.98<br>** | 4.93         | 16.83        |
|           | SE (sij)                      | 0.96         | 0.80         | 0.53         | 0.46         | 0.25         | 0.22         | 5.19         | 4.37         | 0.44         | 0.38         | 10.06        | 9.11         |
|           | CD AT 5%                      | 1.92         | 1.60         | 1.06         | 0.92         | 0.50         | 0.44         | 10.41        | 8.76         | 0.88         | 0.76         | 20.13        | 18.25        |

\*\*\* significant at 5% and 1% level of significance respectively.

## Plant Height

Heterosis over better parents for plant height was estimated over highest of parents of the cross hence, cross with positive heterosis were considered as desirable. The extent of heterosis over better parent ranged from 31.02 (Assury × JB-6) to -27.41 (F.Collection-2 × JB-6) and from 33.76 (Assury × JB-6) to -18.02 (JBL-03-04 × A. Parthibha) percent over mid parent, Among all the 28 hybrids 19 crosses showed significant positive heterosis and 9 crosses showed significant negative heterosis over better parent and mid parent, respectively.

### Primary branches per plant

Heterosis over better parents for Primary branches per plant was estimated over highest of parents of the cross hence, crosses with positive heterosis were considered as desirable. The extent of heterosis over better parent ranged from 64.52 (F.Collection-2  $\times$  DBL-24) to -14.63 (JB-6  $\times$  A. Parthibha) and from 83.76 (F.Collection-2  $\times$  JB-6) to -2.10 (JB-6  $\times$  A. Parthibha) percent over mid parent, Among all the 28 hybrids 20 crosses showed significant positive heterosis and 8 crosses showed significant negative heterosis over better parent and 27 crosses showed significant positive heterosis and 1 cross showed significant negative heterosis over mid parent respectively.

### Plant spread (cm)

Heterosis over better parents for Plant spread was estimated over highest of parents of the crosses. Hence, crosses with positive heterosis were considered as desirable. The extent of heterosis over better parent ranged from 48.22 (JB-6  $\times$  KS-331) to -28.45 (Assury  $\times$  A. Abhilomb) and from 61.43 (JB-6  $\times$  KS-331) to -14.27 (Assury  $\times$  A. Abhilomb) percent over mid parent, Among all the 28 hybrids, 15 crosses showed significant positive heterosis and 13 crosses showed significant negative heterosis over better parent and 21 crosses showed significant positive heterosis and 7 cross showed significant negative heterosis over mid parents.

### Days to first flowering

The negative heterosis was considered desirable for days to first flowering, the extent of heterosis ranged from 16.53 (F.Collection-2  $\times$  A. Abhilomb) to -23.87 (Assury  $\times$  JB-6) percent heterosis over better parent, while it ranged from 14.90 (F.Collection-2  $\times$  A. Abhilomb) to -24.92 (Assury  $\times$  JB-6) percent over mid parent. Among the all 28 hybrids 16 crosses showed significant positive heterosis

and 12 crosses showed significant negative heterosis over better parent and 12 crosses showed significant positive heterosis and 16 cross showed significant negative heterosis over mid parents. The cross Assury  $\times$  JB-6 found to be best showing significant highly negative heterosis over better and mid parent for this trait.

### Days to first fruit set

The negative heterosis was considered desirable for days to first fruit set, the extent of heterosis ranged from 17.32 (F.Collection-2  $\times$  A. Abhilomb) to -22.85 (Assury  $\times$  JB-6) percent heterosis over better parent, while it ranged from 15.83 (F.Collection-2  $\times$  A. Abhilomb) to -24.16 (Assury  $\times$  JB-6) percent over mid parent. Among all the 28 hybrids 18 crosses showed significant positive heterosis and 10 crosses showed significant negative heterosis over better parent and 14 crosses showed significant positive heterosis and 14 cross showed significant negative heterosis over mid parents. The cross Assury  $\times$  JB-6 found to be best showing significant highly negative heterosis over better and mid parent for this trait.

### Days to first fruit picking

The negative heterosis was considered desirable for days to first fruit picking, the extent of heterosis ranged from 19.24 (F.Collection-2  $\times$  A. Abhilomb) to -23.06 (Assury  $\times$  JB-6) percent heterosis over better parent, while it ranged from 16.00 (F.Collection-2  $\times$  A. Abhilomb) to -23.48 (Assury  $\times$  JB-6) percent over mid parent. Among all the 28 hybrids 17 crosses showed significant positive heterosis and 11 crosses showed significant negative heterosis over better parent and 10 crosses showed significant positive heterosis and 18 cross showed significant negative heterosis over mid parents. The cross Assury  $\times$  JB-6 found to be best showing significant highly negative heterosis over better and mid parent for this

trait.

### **Fruit weight (g)**

The positive heterosis was considered desirable for fruit weight, the extent of heterosis ranged from 34.81 (A. Parthibha  $\times$  A. Abhilomb) to -35.13 (F.Collection-2  $\times$  DBL-24) percent heterosis over better parent, while it ranged from 44.96 (A. Parthibha  $\times$  A. Abhilomb) to -30.09 (Assury  $\times$  A. Abhilomb) percent over mid parent. Among all the 28 hybrids 20 crosses showed significant positive heterosis and 8 crosses showed significant negative heterosis over better parent and 24 crosses showed significant positive heterosis and 4 cross showed significant negative heterosis over mid parents. The cross A. Parthibha  $\times$  A. Abhilomb found to be best showing significant highly positive heterosis over better and mid parent for this trait.

### **Length of fruit (cm)**

The highly significant positive heterosis was considered desirable for Length of fruit, the extent of heterosis ranged from 29.45 (JBL-03-4  $\times$  DBL-24) to -33.33 (F.Collection-2  $\times$  KS-331) percent heterosis over better parent, while it ranged from 46.11 (JBL-03-4  $\times$  DBL-24) to -20.79 (Assury  $\times$  JB-6) percent over mid parent. Among all the 28 hybrids 10 crosses showed significant positive heterosis and 18 crosses showed significant negative heterosis over better parent and 18 crosses showed significant positive heterosis and 10 cross showed significant negative heterosis over mid parents. The cross (JBL-03-4  $\times$  DBL-24) found to be best showing significant highly positive heterosis over better and mid parent for this trait.

### **Diameter of fruit (cm)**

The highly significant positive heterosis was considered desirable for diameter of fruit, the extent of heterosis ranged from 83.50 (JBL-03-4  $\times$  JB-6) to -37.89 (A. Parthibha  $\times$  DBL-24) percent heterosis over better parent,

while it ranged from 97.88 (JBL-03-4  $\times$  JB-6) to -16.95 (JBL-03-4  $\times$  A. Abhilomb) percent over mid parent. Among all the 28 hybrids 6 crosses showed significant positive heterosis and 22 crosses showed significant negative heterosis over better parent and 18 crosses showed significant positive heterosis and 10 cross showed significant negative heterosis over mid parents. The cross JBL-03-4  $\times$  JB-6 found to be best showing significant highly positive heterosis over better and mid parent for this trait.

### **Fruit Index**

The highly significant positive heterosis was considered desirable for fruit index, the extent of heterosis ranged from 58.44 (JBL-03-4  $\times$  JB-6) to -41.89 (F.Collection-2  $\times$  DBL-24) percent heterosis over better parent, while it ranged from 69.79 (JB-6  $\times$  A. Abhilombh) to -15.34 (Assury  $\times$  A. Abhilombh) percent over mid parent. Among all the 28 hybrids 11 crosses showed significant positive heterosis and 17 crosses showed significant negative heterosis over better parent and 20 crosses showed significant positive heterosis and 8 crosses showed significant negative heterosis over mid parents. The cross JBL-03-4  $\times$  JB-6 and JB-6  $\times$  A. Abhilombh found to be best showing significant highly positive heterosis over better and mid parent for this trait.

### **Number of fruits per plant**

The highly significant positive heterosis was considered desirable for number of fruits per plant, the extent of heterosis ranged from 14.67 (A. Parthibha  $\times$  DBL-24) to -47.25 (JBL-03-4  $\times$  F.Collection-2) percent heterosis over better parent, while it ranged from 22.98 (A. Parthibha  $\times$  DBL-24) to -27.07 (JBL-03-4  $\times$  F.Collection-2) percent over mid parent. Among all the 28 hybrids 4 crosses showed significant positive heterosis and 24 crosses showed significant negative heterosis over better parent and 10 crosses showed

significant positive heterosis and 18 cross showed significant negative heterosis over mid parents. The cross JBL-03-4  $\times$  F.Collection-2 found to be best showing significant highly positive heterosis over better and mid parent for this trait.

### **Yield of fruit per plant**

The highly significant positive heterosis was considered desirable for yield of fruit per plant, the extent of heterosis ranged from 32.08 (A. Abhilomb  $\times$  DBL-24) to -34.39 (Assury  $\times$  A. Abhilomb) percent heterosis over better parent, while it ranged from 56.97 (A. Abhilomb  $\times$  DBL-24) to -30.07 (Assury  $\times$  A. Abhilomb) percent over mid parent. Among all the 28 hybrids 20 crosses showed significant positive heterosis and 8 crosses showed significant negative heterosis over better parent and 23 crosses showed significant positive heterosis and 5 cross showed significant negative heterosis over mid parents. The cross A. Abhilomb  $\times$  DBL-24 found to be best showing significant highly positive heterosis over better and mid parent for this trait.

Among the 28 hybrids the significant heterosis effects in desirable direction was observed over their respective better and mid for all characters. Increase and decrease in the performance of  $F_1$  over better parent and mid parent in respect of all the characters under study. Increase and decrease in the performance of  $F_1$  over better parent and mid parent in respect of all the characters. Heterosis over better parents for plant height was estimated over highest of parents of the cross. Among all the 28 hybrids 19 crosses showed significant positive heterosis and 9 crosses showed significant negative heterosis over better parent and mid parent, respectively. Heterosis over better parents for primary branches per plant was estimated over highest of parents of the cross. Among all the 28 hybrids 20 crosses showed significant positive heterosis and 8 crosses showed

significant negative heterosis over better parent and 27 crosses showed significant positive heterosis and 1 cross showed significant negative heterosis over mid parent respectively, heterosis over better parents for plant spread was estimated over highest of parents of the crosses. Among all the 28 hybrids 15 crosses showed significant positive heterosis and 13 crosses showed significant negative heterosis over better parent and 21 crosses showed significant positive heterosis and 7 cross showed significant negative heterosis over mid parents. The negative heterosis was considered desirable for days to first flowering, all 28 hybrids 16 crosses showed significant positive heterosis and 12 crosses showed significant negative heterosis over better parent and 12 crosses showed significant positive heterosis and 16 cross showed significant negative heterosis over mid parents. The cross Assury  $\times$  JB-6 found to be best showing significant highly negative heterosis over better and mid parent for this trait. Similar results shown by (1, 2, 11) coined the term heterosis for the special stimulus of heterozygosis upon cell division, growth and other physiological activities of an organism and in 1948 he defined heterosis to cover the real observable phenomenon when unlike gametes are brought together to form a hybrid. (3) observed the significant positive heterosis for fruit yield, magnitude of which ranged from 9.63% to 74.89% and 8.52% to 72.60% over better parent and standard check, respectively. The negative heterosis was considered desirable for days to first fruit set, among all the 28 hybrids 18 crosses showed significant positive heterosis and 10 crosses showed significant negative heterosis over better parent and 14 crosses showed significant positive heterosis and 14 cross showed significant negative heterosis over mid parents. The negative heterosis was considered desirable for days to first fruit picking, among all the 28 hybrids 17 crosses showed significant positive heterosis and 11

crosses showed significant negative heterosis over better parent and 10 crosses showed significant positive heterosis and 18 cross showed significant negative heterosis over mid parents. The cross Assury  $\times$  JB-6 found to be best showing significant highly negative heterosis over better and mid parent for this trait. The positive heterosis was considered desirable for fruit weight, among all the 28 hybrids 20 crosses showed significant positive heterosis and 8 crosses showed significant negative heterosis over better parent and 24 crosses showed significant positive heterosis and 4 cross showed significant negative heterosis over mid parents. The cross A. Parthibha  $\times$  A. Abhilomb found to be best showing significant highly positive heterosis over better and mid parent for this trait. The highly significant positive heterosis was considered desirable for Length of fruit, among all the 28 hybrids 10 crosses showed significant positive heterosis and 18 crosses showed significant negative heterosis over better parent and 18 crosses showed significant positive heterosis and 10 cross showed significant negative heterosis over mid parents. The cross (JBL-03-4  $\times$  DBL-24) found to be best showing significant highly positive heterosis over better and mid parent for this trait. The highly significant positive heterosis was considered desirable for diameter of fruit, among all the 28 hybrids 6 crosses showed significant positive heterosis and 22 crosses showed significant negative heterosis over better parent and 18 crosses showed significant positive heterosis and 10 cross showed significant negative heterosis over mid parents. The cross JBL-03-4  $\times$  JB-6 found to be best showing significant highly positive heterosis over better and mid parent for this trait. The highly significant positive heterosis was considered desirable for fruit index, among all the 28 hybrids 11 crosses showed significant positive heterosis and 17 crosses showed significant negative heterosis over better parent and 20 crosses showed

significant positive heterosis and 8 crosses showed significant negative heterosis over mid parents. The cross JBL-03-4  $\times$  JB-6 and JB-6  $\times$  A. Abhilomb h found to be best showing significant highly positive heterosis over better and mid parent for this trait. The highly significant positive heterosis was considered desirable for number of fruits per plant, among all the 28 hybrids 4 crosses showed significant positive heterosis and 24 crosses showed significant negative heterosis over better parent and 10 crosses showed significant positive heterosis and 18 cross showed significant negative heterosis over mid parents. The cross JBL-03-4  $\times$  F.Collection-2 found to be best showing significant highly positive heterosis over better and mid parent for this trait. The highly significant positive heterosis was considered desirable for yield of fruit per plant, among all the 28 hybrids 20 crosses showed significant positive heterosis and 8 crosses showed significant negative heterosis over better parent and 23 crosses showed significant positive heterosis and 5 cross showed significant negative heterosis over mid parents. The cross A. Abhilomb  $\times$  DBL-24 found to be best showing significant highly positive heterosis over better and mid parent for this trait. Similar results shown by (4, 6, 8, 5) studied the improvement work was concentrated in several organizations with the objective to develop high yielding varieties.

## **CONCLUSION**

These results indicate the scope of selection from various crosses for crop improvement with maximum heterosis effect among improved hybrids combinations (A. Parthibha  $\times$  A. Abhilomb, JB-6  $\times$  DBL-24, F.Collection-2  $\times$  A. Abhilomb, F. Collection-2  $\times$  A. Parthibha (C.K.) were extremely useful for studying the genetic relationship between brinjal genotypes. Crosses A. Parthibha  $\times$  A. Abhilomb, JB-6  $\times$  DBL-24, F.Collection-2  $\times$  A.

Abhilomb, F. Collection-2 x A. Parthibha (C.K.) showed great breeding progress from the other combinations. Finally, these studies have given important clues in understanding genotypes relationship, which may further assist in developing and planning breeding strategies.

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## IMPACT ANALYSIS OF KNOWLEDGE LEVELS (KLS) AND FRONTLINE DEMONSTRATIONS (FLDS) ON YIELD, ECONOMICS AND ADOPTION OF MARIGOLD CULTIVATION TECHNIQUES IN WESTERN UTTAR PRADESH CONDITION

Virendra Pal<sup>1</sup>, Vipin Kumar<sup>2</sup> and Mukesh Kumar<sup>3</sup>

<sup>1</sup>Krishi Vigyan Kendra, Babugarh, Hapur, S.V P. Univ. of Agriculture & Technology, Meerut (UP)

<sup>2&3</sup>Department of Horticulture, S.V P. University of Agriculture & Technology, Meerut (UP)-250110

\*Corresponding Author E-mail– [dr.vipin.kumar.ad@gmail.com](mailto:dr.vipin.kumar.ad@gmail.com)

### ABSTRACT

The knowledge levels and front line demonstrations study was observed in Meerut and Hapur districts condition with the part of western Uttar Pradesh. The totally ten villages, Meerut district in six villages *viz.*, Hastinapur, Ganeshpur, Phulabda, Lawar, Dabka and Pipli khera and Hapur district in four villages *viz.*, Bagarpur, Tatarpur, Garmukteswar and Simroulli were randomly selected, further four blocks namely in Hastinapur, Mawana, Sardhana and Kharkhonda in Meerut district and two blocks particular in Hapur and Garmukteswar were selected. From each block 10 farmers were selected. Thus, in all 60 farmers were randomly selected. The finding indicated on cost returns aspect of marigold cultivation. The data collected on during 2017-18, 2018-19 and 2019–20 was subjected to the anglicized. The Krishi Vigyan Kendra, conducted the knowledge levels and frontline demonstrations on marigold crop during years 2018 to 2020 in the objective to determine the impact on yield, adoption and economic impact of marigold cultivation. The majority of the farmers (76.7 %) were having medium levels of knowledge and favourable attitude about advantages of marigold production techniques. The major constraints noticed were the non availability of pure seeds in nearby market and lack of knowledge about the production techniques. The farmer practice was considered as local check in demonstration field. These check plots were maintained by the farmers according to their own traditional cultivation practices. The KVK provided critical inputs such as seed of improved varieties *viz.*, Pusa Narangi, Pusa Basanti and Pusa Arpita required agro chemicals to the farmers under demonstration plots. The findings showed an increase in the average yield of demonstration plot (167.23 q/ha) over the control local check (125.33 q/ha) of marigold crop. There was a positive impact on the yield of marigold crop, replacement of local varieties with improved varieties such as Pusa Narangi, Pusa Basanti & Pusa Arpita and adoption of production technologies of marigold crop. The adoption of improved technology under FLDs resulted in higher gross income (Rs 2,17,415/-ha), net income (Rs 1,69,115/- ha) and benefit: cost ratio (4.47:1) as compared to farmer's practice.

**Keywords:** Adoption, Cultivation, Demonstrations, Economics, Marigold seed & Yield.

## INTRODUCTION

There is expansive or wide potential for growing flowers because the Meerut district areas can be effectively, virtually and successfully put under the cultivation of marigold. Due to weather is good for better in marigold cultivation during period and availability of irrigation facility, potential seeds and fertilizers, farmers in Meerut district areas, Western Uttar Pradesh conditions. Hastinapur, Ganeshpur, Phulabda, Lawar, Dabka and Pipli Khera villages district in Meerut and Bagarapur, Tatarpur, Garmukteswar and Simroulli villages district in Hapur can be grown these flowers throughout the year. As these villages were well connected by road, there will be no problem of marketing also. There is also near NCR New Delhi area, due to huge demand and supply gap of flowers in the local market, the traders directly come to the farmers field to collect fresh flowers regularly.

The recommendations for suitable high yielding varieties of flowers were also available with the IARI, New Delhi. Thus, it was hypothesized that cultivation of marigold will improve the household economy of flowers in the villages.

For accelerating the use of many techniques, it is essential to train the farmers, encourage them to use marigold production techniques in their field for cultivation. In order to know the existing level of knowledge about production techniques and attitude of farmers towards technology, its actual use, constraints faced by the farmers while using technology in the fields. The majority of the farmers of the farmers (76.7 %) were having medium levels of knowledge and favourable attitude about advantages of marigold production techniques and Front line demonstrations (FLDs) a flagship programme on farmer's field is one of the mandates of krishi vigyan

kendra. Therefore, KVK emphasized the frontline demonstration as an educational activity in a systematic manner at farmers' fields to show the worth of new technology/enterprise. Floriculture especially marigold cultivation can be a major thrust area for diversification. The commercial cultivation of marigold can be a good source of income and employment to marginal as well as large farmers as this crop fetches more price per unit area as compared to sugarcane and cereals. The farmers of Meerut and Hapur districts were growing traditional crops and getting crops during 2017 to 2020 in different villages of Meerut and Hapur district on 6.0 ha area. Therefore, the present investigation was carried out in ten adopted villages purposively. The FLDs were conducted on farmer's fields according to package of practices recommended by Department of Horticulture, Sardar Vallabhbhai Patel University of Agriculture & Technology Meerut (UP). The farmer's practice was considered as local check in demonstration field. These check plots were maintained by the farmers according to their own traditional cultivation practices. The KVK provided critical inputs such as seed of improved varieties viz. Pusa Basanti, Pusa Narangi and Pusa Arpita required agro chemicals to the farmers under demonstration plots. The demonstrations were laid out under the close supervision of KVK, Horticulture scientists and Deptt. of Horticulture, Professor's (Floriculture & Landscaping) with experts. Total 60 farmers were selected for the organization of FLDs on marigold crop in the above mentioned villages. The average yield data of demonstration plots as well as control plots were collected after harvesting to assess the impact of FLDs intervention on the yield of marigold crop. The personal interview was conducted with the beneficiary farmers in the year 2020 by using structured and pre-tested interview schedule to elicit the information from beneficiary farmers about adoption, varietal replacement and horizontal spread of

marigold crop technologies in adopted villages. The following formulae were used to assess the impact of trainings and FLDs on the different parameters of marigold crop.

## MATERIALS AND METHODS

The investigation was conducted in the totally ten villages, Meerut district in six villages *viz.*, Hastinapur, Ganeshpur, Phulabda, Lawar, Dabka and Pipli khera and Hapur district in four villages *viz.*, Bagarapur, Tatarpur, Garmukteswar and Simroulli were randomly selected, further four blocks namely in Hastinapur, Mawana, Sardhana and Kharkhonda in Meerut district and two blocks particular in Hapur and Garmukteswar were selected. From each block 10 farmers were selected. Thus, in all 60 farmers were randomly selected of Meerut and Hapur districts. Krishi Vigyan Kendra conducted the FLDs on floriculture a marigold crop meagre income from the agriculture. To motivate the farmers towards diversification and bring floriculture as a subsidiary source of income in addition to their already adopted farming, All the villages is disseminating knowledge about marigold production technology through lectures, training programme, demonstrations, exhibitions and its adoption in marigold crop production system at farmers level. FLD's on marigolds were conducted by KVK Meerut and Hapur districts during the years 2017 to 2020. About 168.5 ha of land (2016-17) was under floriculture in district Western Uttar Pradesh which included major share of marigold cultivation (Anon, 2016). Hence, the study was undertaken to assess the impact of trainings and frontline demonstrations on yield and adoption of marigold crop, to know the varietal replacement and its economic impact.

- Impact on yield (% change) = Yield of

demonstration plot –Yield of control plot x 100 / Yield of control plot

- Impact on adoption (% change) = No. of adopters after FLD - No. of adopters before FLD x 100 No. of adopters before FLD

## Knowledge levels

Total number of knowledge levels was 18.3 each of them was scored zero and one for 'no' knowledge and 'complete' knowledge, respectively on the part of the respondents. The knowledge for an individual respondent was arrived at by using the following formula:

$$\text{Knowledge} = \text{Score obtained} \times 100 / 18.3$$

**Table 1. Distribution of farmers according to the knowledge and attitude towards marigold production technology.**

| S.Nos. | Variable and Category | Farmers (N-60) |            |
|--------|-----------------------|----------------|------------|
|        |                       | Number         | Percentage |
| 01.    | Knowledge levels:     |                |            |
|        | Low                   | 05             | 8.3        |
|        | Medium                | 46             | 76.7       |
|        | High                  | 08             | 13.3       |
| 02.    | Attitude:             |                |            |
|        | Least favourable      | 11             | 18.3       |
|        | Favourable            | 39             | 65.0       |
|        | Most favourable       | 19             | 31.7       |

## Attitude

To measure the level of attitude of respondents towards marigold production technology questions were prepared on the basis available literature, discussion with experts in the related field and personal experience. The respondents were classified into three groups namely least favourable, favourable and most favourable.

## RESULTS AND DISCUSSION

Impact on crop yield It was evident (Table 2) that the average flower yields of demonstration plots of marigold varieties Pusa Narangi, Pusa Basanti and Pusa Arpita for the years 2017- 18, 2018-19 and 2019-20 were 167.35, 168.60 and 165.75q/ha. However, the average flower yields of control plot/ local

check were 123.0, 128.0 and 125.0 q/ha in the years 2017-18, 2018-19 and 2019-20 respectively. This showed that there was a positive increase in the mean yield of marigold demonstration plots over the farmer's practice by 36.05, 31.71 and 32.60 per cent during the years 2017-18, 2018-19 and 2019-20, respectively. The main reasons of the low yield of control plots in adopted villages were the use of poor quality seeds, traditional varieties and traditional cultivation methods with poor nutrient and weed management practices. However, KVK scientists used improved varieties of seed, adopted scientific cultivation practices like timely sowing, pinching, recommended spacing, balanced use of manure and fertilizers with time to time weed management and integrated disease management for the demonstration plots which recorded 33.45 per cent higher mean yield over that of control plots. Similar results were obtained by Khadekar et al (2017) in chick pea FLD's and (5) in oilseed crops. There was a positive impact on flower yield by use of improved varieties and scientific package of practices. (6) indicated that the existing local cultivar Saathi or Jafri of marigold was outperformed by the variety Pusa narangi in all the crop growth parameters in Malwa region of Madhya Pradesh. The improved variety was significantly taller than the local by more than 31 cm.

**Table 2. Impact of Frontline demonstrations on marigold crop yield.**

| Years   | Varieties                  | No. of farmers | Demonstrated area (ha) | Average yield (q/ha) |                           | Impact (% change) |
|---------|----------------------------|----------------|------------------------|----------------------|---------------------------|-------------------|
|         |                            |                |                        | Check plot (q/ha)    | Demonstration plot (q/ha) |                   |
| 2017-18 | Pusa Narangi               | 10             | 1.0                    | 123.0                | 167.35                    | +36.05            |
| 2018-19 | Pusa Narangi               | 30             | 3.0                    | 128.0                | 168.60                    | +31.71            |
| 2019-20 | Pusa Basanti & Pusa Arpita | 20             | 2.0                    | 125.0                | 165.75                    | +32.60            |
|         | Total                      | 60             | 6.0                    | 125.3                | 167.23                    | +33.45            |

## Impact on Economics

The inputs and outputs prices of commodities prevailed during the study of demonstration were taken for calculating net income and benefit: cost ratio (Table 3). The data indicated that cultivation of marigold under improved technologies gave higher net income of Rs. 2,02,425/-, 1,53,820/- and 1,51,1000/- ha in the years 2017-18, 2018-19 and 2019-20, respectively as compared to farmer's practices. Similar findings were reported by Khadekar et al (2017) in chickpea cluster FLDs. The benefit cost ratio of marigold cultivation under improved cultivation practices were 5.16:1, 4.17:1 and 4.10:1 where as they were 4.47:1 and 3.70:1 in farmer's practices during 2017-18, 2018-19 and 2019-20 respectively. This may be due to higher yield obtained under improved technologies compared to local check (farmer's practice). This finding was in corroboration with the findings of (2) for wheat.

**Table 3. Impact of front line demonstration on economics of marigold cultivation.**

| Years   | Cost of cultivation (Rs/ha) |            | Gross income (Rs/ha) |            | Net income (Rs/ha) |            | B:C Ratio |            |
|---------|-----------------------------|------------|----------------------|------------|--------------------|------------|-----------|------------|
|         | Demo plot                   | Check plot | Demo plot            | Check plot | Demo plot          | Check plot | Demo plot | Check plot |
| 2017-18 | 48600                       | 41500      | 251025               | 184500     | 202425             | 143000     | 5.16:1    | 4.44:1     |
| 2018-19 | 48500                       | 41200      | 202320               | 153600     | 153820             | 112400     | 4.17:1    | 3.72:1     |
| 2019-20 | 47800                       | 40200      | 198900               | 150000     | 151100             | 109800     | 4.10:1    | 3.70:1     |
| Mean    | 48300                       | 40966      | 217415               | 162700     | 169115             | 121733     | 4.47:1    | 3.95:1     |

## Impact on Adoption

The data (Table 4) revealed that a number of adopters person for land preparation and application of FYM to marigold were 126 before demonstrations, which increased to 161 after frontline demonstrations in adopted villages. A similar trend was also observed in the case of use of improved varieties and sowing time and spacing as the percentage of adopters increased from 41 to 138 and 52 to 132. The number of adopters for application of fertilizers and weed management were

increased during pre and post-demonstrations period from 35 to 122 and from 18 to 78, respectively. The FLDs intervention made highly positive impact on adoption of technologies as majority of the participant farmers in FLD program had full adoption of improved practices viz., land preparation, use of high yielding varieties, sowing time, spacing application of manures and fertilizer with IPM, weed management operations and integrated disease management.

**Table 4. Impact of frontline demonstration on adoption of marigold production technology.**

| S. Nos. | Technology                         | Number of adopters (N-60) |             | Change in no. of adopters | Impact (% change) |
|---------|------------------------------------|---------------------------|-------------|---------------------------|-------------------|
|         |                                    | Before demo.              | After demo. |                           |                   |
| 01.     | Land preparation & use of FYM      | 126                       | 161         | +35                       | +27.77            |
| 02.     | Improved varieties                 | 41                        | 138         | +97                       | +236.58           |
| 03.     | Sowing time and spacing            | 52                        | 132         | +80                       | +153.84           |
| 004.    | Fertilizer management & IPM        | 35                        | 122         | +87                       | +248.57           |
| 05.     | Weed management & IDM              | 18                        | 78          | +60                       | +333.4            |
| 06.     | Pinching off operation (30-40 DAT) | 21                        | 132         | +111                      | +528.57           |

## CONCLUSION

The present study indicated that the farmers were medium in knowledge level and favourable in attitude about marigold production technology. Important constraints in adoption of production technology faced by farmers were non availability of seeds in nearby market, lack of knowledge or guidance about preparation of minor techniques. The frontline demonstrations (FLDs) organized by the KVK Meerut and Hapur districts enhanced the production of marigold crop. The FLDs made a positive and significant impact on yield of marigold by 33.45 per cent. The FLDs showed a great impact on the use of improved varieties, intercultural operation

viz., pinching off and adoption of other recommended practices of the crop. The local varieties of marigold crop were replaced by improved cultivars like Pusa Narangi, Pusa Basanti and Pusa Arpita on a large scale in demonstration fields. Therefore, it can be concluded that FLDs had positive impact in enhancing the marigold crop productivity and adoption of floriculture as an enterprise. Therefore, it is recommended that frontline demonstrations (FLDs) may be organized on large scale by adopting cluster approach for harnessing the productivity potential of a crop and to ensure rapid spread of flagship technologies. Most of the low yielding local Varieties (Saathi and Jafri) were replaced due to FLDs in adopted villages. This varietal replacement strategy through FLDs may help to increase the crops productivity at micro and macro level. The positive and significant relationship between the knowledge and attitude revealed the fact that if farmers had good knowledge with positive attitude towards the production technology, it results in its better adoption. Hence, extension efforts should be directed these constraints in order to increase level by the farmers.

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## EFFECT OF MANAGED POLLINATION USING APIS MELLIFERA LINNAEUS COLONIES ON YIELD CHARACTERISTICS OF RADISH, RAPHANUS SATIVUS LINNAEUS

Pushpinder Kaur Brar<sup>1</sup>, GS Gatoria<sup>2</sup>, Pardeep K Chhuneja<sup>3</sup> and Nirmal Singh<sup>4</sup>

<sup>1,2,3</sup>Department of Entomology, Punjab Agricultural University, Ludhiana

<sup>4</sup>Krishi Vigyan Kendra, Guru Angad Dev Veterinary and Animal Sciences university, Tarn Taran

\*Corresponding Author E-mail– @gmail.com

### ABSTRACT

Studies at a farmer's field on radish cv. Pusa Chetki during its blooming phase in the Punjab (India) involving four treatments *viz.* E1 : crop caged enclosing 4-bee-frame strength *Apis mellifera* colony hive with one entrance inside the nylon netting cage, E2 : crop caged enclosing the colony hive having two entrances (front one inside the cage and the second in the rear of hive outside the cage), OP : open pollination, and PE : the crop caged without bees to exclude the pollinators, revealed that foraging rate and foraging intensity of the bee species were maximum under open pollination treatment (9.98 flowers/min and 4.46 bees/m<sup>2</sup>/min, respectively), during peak blooming phase (9.29 flowers/min and 3.87 bees/m<sup>2</sup>/min, respectively) of the crop and at 1200 h (9.74 flowers/min and 4.48 bees/m<sup>2</sup>/min, respectively). Yield determining characteristics including siliquae setting, seed setting, seed weight and seed yield per plant were the highest in open pollinated plots followed by in plots caged enclosing the bee colony hive with two entrances and plots caged with the bee colony hive with only one entrance, in decreasing order. Seed yield increase per unit area over pollinators' exclusion (PE) was 29.60, 24.53 and 22.49 per cent under open pollination (OP), under two entrance hive (E2) and one entrance hive (E1) treatments, respectively. Seed germination and seed vigour were the highest in OP treatment followed by, in decreasing order, in E2, E1 and PE treatments, respectively.

**Keywords:** *Apis mellifera*, foraging intensity, foraging rate, honey bee, pollination, pollinator, radish, *Raphanus sativus*, seed production, seed yield.

### INTRODUCTION

Radish (*Raphanus sativus* Linnaeus), an important root vegetable crop grown from tropical to temperate climates, is grown throughout the year due to the availability of its season specific cultivars. It is primarily grown for edible roots and leaves used as salad, roots used in pickles and all the three plant parts i.e. leaves, roots and

siliquae / *mongra* cooked as vegetable dishes. Besides providing carbohydrates, proteins and some fat, radish is rich in minerals, vitamin A, fibre content, ascorbic acid, pectin and cellulose (3, 6, 11). Being useful for curing liver and gall bladder problems and its root extract showing antimicrobial activities against several bacteria pathogenic to the human, radish is known for its medicinal importance (1).

Due to sporophytic self-incompatibility, radish is a cross pollinated crop but wind is not considered as an important agent for its pollination. Insects, particularly the honey bees are, however, known to play important role in its pollination (8, 14, 15, 16). Hive honey bees are the best pollinators of entomophilous crops because these can be managed on crops whenever, wherever and in whatever number required. Honey bees also exhibit behaviour of floral constancy. Hence, the hive bees are considered as more dependable pollinators. The use of hive honey bees for pollination could, thus, be a strategy for enhancing radish seed yield. In radish, seed yield increase has been reported by providing adequate number of pollinators (14, 16, 18). (18) also reported radish to be a good source of pollen and the blooms pollinated by honey bees produced significant increase in seed yield and quality. *Apis mellifera* Linnaeus beekeeping is being very fast adopted almost throughout India but in the Punjab state, this is the only honey bee recommended for hiving. The studies on the extent of yield increases in radish through managed pollination by *A. mellifera* are lacking in the country in general and in the Punjab, in particular. Present study on the pollination of radish by *A. mellifera* was, therefore, planned to evaluate the effect of intensive pollination by the bee on the crop yield characteristics.

## MATERIALS AND METHODS

This experiment was conducted on radish crop (cv. Pusa Chetki) at a farmer's crop field in village Sudhar, District Ludhiana (Punjab : India) for seed production as per the recommendations of Punjab Agricultural University (2). There were four treatments, each replicated five times, as given below:

E1: Crop caged (covered) with nylon

netting enclosing one 4-bee-frame strength *A. mellifera* colony hive having only one entrance inside the cage.

E2: Crop caged as above enclosing 4-bee-frame strength *A. mellifera* colony hive with two entrances - one frontal inside the cage and the second in the rear of the hive opening outside the nylon netting cage.

OP: Open pollination i.e. crop having free access to all natural pollinators (crop not caged).

PE : Crop caged with nylon netting without bees (pollinators' exclusion).

The nylon netting cages (3m x 6m x 2m) were erected just at the initiation of the crop blooming. Bee activity, including foraging rate and intensity of *A. mellifera* population, was recorded four times (at weekly interval) during the blooming phase of the crop (February 15, February 22, March 1 and March 8), three times on the above observation days i.e. at 0900 h, 1200 h and 1500 h. At the time of crop maturity, observations on various yield determining characteristics were recorded from every replicated plot as per given:

- a. Number of siliquae per plant (on the basis of ten tagged plants per replication)
- b. Number of seeds per siliqua (on the basis of twenty siliquae from every tagged plant)
- c. Thousand seed weight from every tagged plant
- d. Seed yield per plant and per unit area
- e. Seed germination percentage (wet paper method) using 100 seeds from every tagged plant
- f. Seedling vigour index (seedling length x germination percentage) using wet paper method with 100 seeds

The data on the comparative foraging activity of bees have been depicted as bar diagrams and those on yield determining parameters were statistically analyzed using Randomized Block Design and treatment means compared using L.S.D. ( $p=0.05$ ).

## RESULTS AND DISCUSSION

### RESULTS

#### Foraging activity

Foraging rate of *A. mellifera* during different times of the day in different pollination treatments and at different dates/weeks (Fig. 1) was the maximum at peak blooming of the crop on February 22 (9.29 flowers/min). Foraging rate was recorded as 8.92, 7.62 and 9.80 flowers/min under E1, E2 and OP treatments, respectively. The number of flowers visited was the highest at 1200 h (9.74 flowers/min) and the lowest at 0900 h (7.94 flowers/min).

The maximum foraging intensity (Fig. 2) of *A. mellifera* was recorded again at peak blooming of the crop i.e. on February 22 (3.87 bees/m<sup>2</sup>/min). Foraging intensity was significantly the highest in OP plots (4.46 bees/m<sup>2</sup>/min) followed by in E2 plots (3.38 bees/m<sup>2</sup>/min) and E1 plots (2.30 bees/m<sup>2</sup>/min). During the day, it was the highest at 1200 h (4.48 bees/m<sup>2</sup>/min).

#### Yield characteristics

The effect of various pollination treatments on the following yield determining parameters was recorded (Table 1).

#### Siliquea setting

The mean number of siliquae per plant was found to be 944.54, 769.05, 561.02 and 448.94 in OP, E2, E1 and PE treatments, respectively. Open pollination plots had 110.39 per cent more siliquae setting over pollinators' exclusion treatment.

#### Seed setting

The mean number of seeds per 20 siliquae was the maximum in OP treatment plots (120.60 seeds) followed by in E2 (110.68 seeds) and E1 treatment plots (101.01 seeds), and the minimum was in PE treatment plots (87.40 seeds).

#### Thousand seed weight

Thousand seed weight did not differ significantly between OP treatment (12.02 g) and E2 treatment (11.75 g), while seed weight was significantly low in E1 treatment plots (11.29 g) and the minimum was in control (PE) plots (10.79 g).

#### Seed yield

Seed yield per plant was 53.63, 43.31, 35.08 and 24.63 g in the OP, E2, E1 and PE treatments, respectively. Seed yield per plot (6×3 m<sup>2</sup>) was 14.36 kg in OP treatment plots followed by 10.74 kg in E2 treatment plots, 9.53 kg in E1 treatment plots and 7.78 kg in PE treatment plots. Significantly the highest yield over control (PE) was recorded in OP treatment (84.53%), followed by in E2 treatment (29.60%) and E1 treatment (22.49%).

#### Seed germination

Seed germination was the highest in seeds in OP treatment plots (94.20 %) followed by in E2 treatment plots (92.40%), E1 treatment plots (89.00%) and in PE treatment plots (81.40%).

#### Seedling vigour index

Seedling vigour was calculated as the product of seed germination percentage and seedling length. Seed vigour index was the maximum (293.86) in open pollinated (OP) plots which was on par with seed vigour of 259.39 in plots caged with *A. mellifera* colony with two entrances (E2). It was 202.90 in plots caged with *A. mellifera* colony with only one inside entrance (E1) and 172.74 in plots caged without bees (PE).

## DISCUSSION

#### Siliquea setting

In an experiment by Priti *et al.* (2001), siliquae setting was more in insect pollinated plots of radish than in self-pollinated plants

(pollinators' exclusion) and increase in fruit setting under bee pollination over selfing was higher by 24.45 per cent. The present studies, where fruit/silique set was 110.39 and 25.00-71.30 per cent higher in open pollinated and plots caged with *A. mellifera* colony having one/ two entrances over plots caged without bees (selfing), respectively, supported the above referred report.

### Seed setting

(14) reported that the number of radish seeds per pod was 8.6 and 4.0 in bee pollinated and self pollinated plots, respectively. (17) reported that the number of seeds per radish pod (silique) was 4.73, 3.30 and 1.94 seeds in open pollinated, caged with bees and self pollinated flowers. The present studies where there were 6.03, 5.05-5.53 and 4.37 seeds per silique in open pollinated, plots caged with *A. mellifera* colony having one or two entrances and in plots caged without bees, respectively, support their results. (9) reported 112.8 per cent higher number of seeds per silique in open pollinated plants of radish as compared with those in cage. In the present studies, mean seeds per silique were 38.05 and 15.79-26.64 per cent higher in open pollinated and plots having bees (*A. mellifera* colony) with one or two entrances, respectively over plots caged without bees.

### Thousand seed weight

(9) reported 21.8 per cent increase in seed weight in open pollinated plants of cv. Japanese White of radish as compared with caged ones (excluding pollinators). (14) also reported 66.67 per cent increase in seed weight in bee pollination over selfing in radish. In the present studies, seed weight in open pollination was 11.39 per cent higher and in plots caged with colony of *A. mellifera* with one/two entrances was 4.63 to 8.89 per cent higher over pollinators' exclusion. (17) recorded weight of 100 radish seeds as 1.609, 1.593 and 1.592 g in open pollinated, caged

with bees and self pollinated plots, respectively. In the present studies, in open pollinated plots, plots caged with bees and plots caged without bees (selfing) resulted in the mean 100 seed weight as 1.202, 1.129-1.175 and 1.079 g, respectively, thereby corroborating the earlier reports.

### Seed yield

(9) reported that open pollinated radish plants had 193.6 per cent higher seed yield per plant than plants caged to exclude insects. According to (12), the use of *Apis cerana* Fabricius to pollinate radish crop increased yield by 18.7 per cent. (4) reported 22.0 to 100 per cent increase in seed yield of radish in bee pollination over self pollination. The usefulness of honey bees in increasing some other cruciferous crops has also been reported. Studies on bee pollination of cauliflower by (7) revealed that seed yield were 22.60, 14.50 and 5.61 g/plant in open pollination, plants caged with a nucleus colony of honey bees (*A. cerana*) and caged without bees, respectively. (13) reported that pollination of *Brassica juncea* by *A. cerana* resulted in maximum yield in open pollination (13.4 q/ha), plots caged with bees (*A. cerana*) yielded 11.3 q/ha while plots caged without bees yielded only 10 q/ha. In the present studies on radish, the seed yield in open pollinated, plots caged with *A. mellifera* colony having one or two entrances resulted in 117.74 per cent and 42.42 to 75.84 per cent increase in yield over plots caged without *A. mellifera* colony on per plant basis and 84.53 per cent and 22.49-29.60 per cent per plot (6 × 3 m<sup>2</sup>) basis, respectively. Thus, the present studies corroborate the earlier findings.

### Seed germination

(7) recorded significantly greater seed germination of *Brassica oleracea* in open pollinated and plots caged with *A. cerana* nucleus colony than in the plots caged without bees. Similarly, study on *Brassica napus* by (10) revealed that seeds from open pollinated

plots had 96.3 per cent germination followed by from the plots enclosed with honey bees (95.0%), while seeds from plants obtained from plots excluded from pollinators had lower mean germination (82.9%). In the present studies also, the seed germination was the highest in open pollination treatment plots (94.20 %) followed by in plots caged with bees (89.00-92.40%) and the lowest in the plots excluded of the bees (81.40%).

It is concluded that yield determining parameters such as siliqua setting, seed weight, seed yield per plant or per plot and percentage yield increase in pollination treatments over exclusion of pollinators were higher in open pollination plots followed by plots caged with honey bee colony hive having two and one entrance in order. This could be due to the effect of better foraging activities of the foragers in these treatments in order as depicted in Fig. 1 and 2. In fact, the State has the largest *A. mellifera* beekeeping activity in the country. *Apis cerana* Fabricius beekeeping is not recommended in the State and very rare

feral colonies of this bee species are spotted here only in the winter season. *Apis dorsata* Fabricius and *Apis florea* Fabricius are also of occasional occurrence and their activity, in general, is lower in winter. Foraging activity of these latter three species on the crop was very low (5). There were 35 *A. mellifera* single chamber colonies only 250 m from the experimental fields. This could also attribute to the higher intensity of *A. mellifera* in open pollinated fields (Fig. 1, 2) and hence could translate into higher yield characteristics. The increased seed germination and seed vigour were also observed in the treatments with higher bee foraging activity.

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allowing to conduct the experiment in his fields.

**Table 1. Effect of pollination by *Apis mellifera* on yield characteristics of radish cv. Pusa Chetki.**

| Treatment                                                               | Siliquae per 10 plants |                                            | Seeds per 20 siliquae |                                            | Thousand seed weight |                                            | Seed yield per plant |                                            | Seed yield per plot (6 × 3m <sup>2</sup> ) |                                            | Seed germination |                                            | Seedling vigour |                                            |
|-------------------------------------------------------------------------|------------------------|--------------------------------------------|-----------------------|--------------------------------------------|----------------------|--------------------------------------------|----------------------|--------------------------------------------|--------------------------------------------|--------------------------------------------|------------------|--------------------------------------------|-----------------|--------------------------------------------|
|                                                                         | No.                    | Increase over exclusion of pollinators (%) | No.                   | Increase over exclusion of pollinators (%) | Mass (g)             | Increase over exclusion of pollinators (%) | Mass (g)             | Increase over exclusion of pollinators (%) | Mass (kg)                                  | Increase over exclusion of pollinators (%) | Per cent*        | Increase over exclusion of pollinators (%) | Index           | Increase over exclusion of pollinators (%) |
| E1 : Crop cage d with <i>A. mellifera</i> colony with one hive entrance | 561.02                 | 25.00                                      | 101.02                | 15.79                                      | 11.29                | 4.63                                       | 35.08                | 42.43                                      | 9.53                                       | 22.49                                      | 89.00<br>(70.66) | 9.36                                       | 202.90          | 17.45                                      |
| E2 : Crop cage with <i>A. mellifera</i> colony with two hive entrances  | 769.05                 | 71.30                                      | 110.68                | 26.64                                      | 11.75                | 8.89                                       | 43.31                | 75.84                                      | 10.74                                      | 29.60                                      | 92.40<br>(74.00) | 13.50                                      | 259.39          | 50.16                                      |
| OP : Open pollination                                                   | 944.54                 | 110.39                                     | 120.60                | 38.05                                      | 12.02                | 11.39                                      | 53.63                | 117.74                                     | 14.36                                      | 84.53                                      | 94.20<br>(76.11) | 16.72                                      | 293.86          | 70.11                                      |
| PE:Pollinators' exclusion                                               | 448.94                 | -                                          | 87.40                 | -                                          | 10.79                | -                                          | 24.63                | -                                          | 7.78                                       | -                                          | 81.40<br>(64.47) | -                                          | 172.74          | -                                          |
| L.S.D.(p=0.05)                                                          | 39.97                  | -                                          | 5.84                  | -                                          | 0.27                 | -                                          | 3.34                 | -                                          | 0.71                                       | -                                          | (1.97)           | -                                          | 54              | -                                          |

\*Figures in parentheses are the means of arc sine  $\sqrt{\text{percentage transformations}}$

Fig. 1. Mean foraging rate of *Apis mellifera* on radish (cv. Pusa Chetki) during crop blooming period

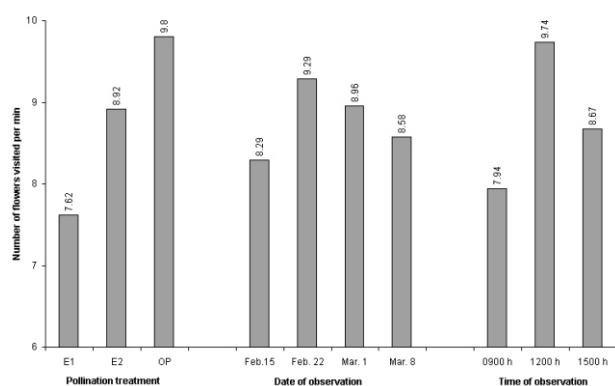
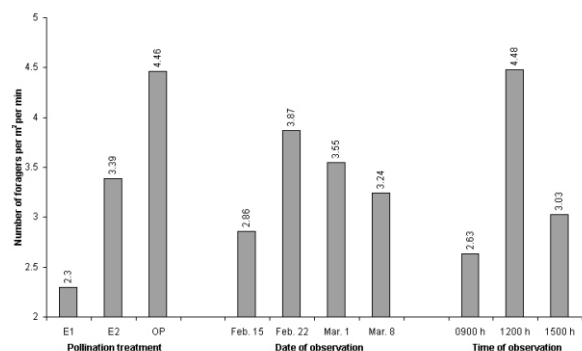


Fig. 2. Mean foraging intensity of *Apis mellifera* on radish (cv. Pusa Chetki) during crop blooming period



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## GENETIC DIVERGENCE STUDIES IN RADISH (*RAPHANUS SATIVUS* L.) UNDER HILLY REGION OF BHARSAR (UTTARAKHAND) IN INDIA

Jakhwal R<sup>1</sup>, Goswami G<sup>2</sup>, Pant S.C., Kumar V<sup>3</sup>, Bahuguna P<sup>4</sup> and Verma S<sup>5</sup>

<sup>1</sup>Department of Vegetable Science, V.C.S.G College of Horticulture  
and Forestry, Bharsar, Pauri Garhwal, Uttarakhand

<sup>2</sup>Dept. of Natural resource Management, V.C.S.G College of Horticulture  
and Forestry, Bharsar, Pauri Garhwal, Uttarakhand

<sup>3</sup>Dept. of Vegetable Science, College of Horticulture, SVPUAT, Meerut

<sup>4</sup>. Department of Basic Science and Humanities, V.C.S.G. College of Horticulture  
and Forestry, Bharsar, Pauri Garhwal, Uttarakhand

<sup>5</sup>Dept. of Food Science and Technology, V.C.S.G College of Horticulture  
and Forestry, Bharsar, Pauri Garhwal, Uttarakhand

\*Corresponding Author E-mail– [riajakhwal1997@gmail.com](mailto:riajakhwal1997@gmail.com)

### ABSTRACT

The present investigation was carried out with 20 genotypes of Radish (*Raphanus sativus* L.) at the Vegetable Research and Demonstration Block, College of Horticulture, Veer Chandra Singh Garhwali, Uttarakhand University of Horticulture and Forestry, Bharsar during rabi season of September 2019 to obtain the knowledge of genetic divergence. The experiment was laid out in RCBD with three replications. In this study, twenty genotypes including one check cultivar Japanese White were evaluated for different horticultural traits. The analysis of variance showed significant variation among different genotypes for all the traits under study. Genetic analysis indicated that phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) in all the attributes studied. On the basis of D<sup>2</sup> statistic, the twenty genotypes were grouped into five divergent. Among the five clusters studied, cluster V was the largest cluster consisting of nine genotypes followed by cluster III with 4 genotypes, cluster I and II with 3 genotypes and Cluster IV with 1 genotype. The highest inter-cluster distance was observed between cluster I and cluster IV (D<sup>2</sup> = 8.606) and lowest for cluster II and cluster III (D<sup>2</sup> = 2.909). Maximum inter-cluster D<sup>2</sup> values were between the clusters I and IV indicated that the genotypes included in these clusters can be used as a parent in hybridization programme to get higher heterotic hybrids from the segregating population.

**Keywords:** Radish, Genetic divergence, D<sup>2</sup> statistics

### INTRODUCTION

Radish (*Raphanus sativus* L.) is a prominent vegetable crop grown worldwide for freshly edible roots (hypocotyls) which is eaten

as fresh crunchy salad and cooked as vegetable or preserved by brining, pickling, canning and drying, the soft leaves are ‘ consumed as a leafy vegetable or used for

chutney preparation. It belongs to family Brassicaceae having chromosome number  $2n = 2x = 18$ . It is commonly known as Muli or Mula which grows in every part of India particularly in Uttar Pradesh, Bihar, West Bengal, Assam, Punjab, Haryana, Himachal Pradesh and Gujarat. Radish also fits well in multiple cropping systems due to its short growing season. The commonly grown radish varieties are classified broadly into two groups; European or Temperate type and Asian or Tropical type. Temperate types are small in size, tastes mild and are mostly raised for salad, whereas tropical types are larger in size, tastes pungent and are mostly raised for salad or also cooked. Seed production of European types is possible only under temperate conditions where chilling temperatures occur. The Asian cultivars with high temperature adaption resist more heat than the European cultivars. Radish is more sensitive to the temperature and photoperiod. The best root shape and higher quality are produced when grown at 15-18 °C (2). The best quality roots are obtained in moderate day length. Bolting is also affected by the day length (5). For developing new high yielding varieties studies on the existing genetic variability in the crop have to be carried out. The study of genetic parameters like genotypic variability, phenotypic variability, genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance are highly useful for carrying out effective selection and improvement of breeding population. The study of correlation and path analysis for yield and yield contributing traits will be helpful in improving the root yield.

## MATERIALS AND METHODS

The present investigations were carried out during *rabi* season 2019 at the Vegetable Demonstration and Research Block Department of Vegetable Science, College of

Horticulture, VCSG, UHF, Bharsar Uttarakhand (India). The experiment was laid out in RCBD method with three replications at spacing of 45 cm × 20 cm. All the recommended cultural practices were followed under irrigated conditions as and when needed. The observations were recorded on five random competitive plants per replication for each genotype of twelve important characters *i.e.* length of whole plant after harvesting, number of leaves at the time of harvesting, root weight with leaves (g), root weight without leaves (g), root length (cm), leaves weight (g), leaf length (cm), root diameter (cm), root yield per plot (kg), per cent dry matter contents (%), ascorbic acid (mg/100gm) and total soluble solids (°Brix). Mahalanobis  $D^2$  statistic (Rao, 1952) has been used to analyze genetic divergence among safflower genotypes (1). The data has been subjected to statistical analysis to calculate genetic divergence genotypic (GCV) and phenotypic (PCV) coefficients of variation, heritability and genetic advance as per cent of mean.

## RESULTS AND DISCUSSION

The analysis of variance indicated that differences among the genotypes were highly significant for all the twelve characters studied. This indicated the presence of appreciable amount of diversity among the genotypes studied. The mean performances of the different traits under study in 20 radish genotypes are shown in Table 1. Significant differences were observed among all the genotypes for all the characters under study. The Mahalanobis  $D^2$  values have grouped the twenty radish genotypes to five distinct clusters. Among the five clusters studied, cluster V was the largest cluster consisting of nine genotypes followed by cluster III with 4 genotypes, cluster I and II with 3 genotypes and Cluster IV with 1 genotype. Among the five clusters, the intra cluster  $D^2$  values ranged from 1.21 to 2.643. Cluster I with 3 genotypes showed maximum intra cluster diversity ( $D^2 =$

2.643) followed by cluster III ( $D^2 = 2.155$ ), cluster II ( $D^2 = 2.138$ ), cluster V ( $D^2 = 1.972$ ) and least intra cluster distance was observed in cluster IV ( $D^2 = 1.21$ ). The highest inter-cluster distance were observed between cluster I and cluster IV ( $D^2 = 8.606$ ) and lowest for cluster II and cluster III ( $D^2 = 2.909$ ), represented in Table 2. Cluster mean for different characters among twenty genotypes of radish represented in Table 3. Maximum inter cluster  $D^2$  values were between the clusters I and IV indicated that the genotypes included in these clusters can be used as a parent in hybridization programme to get higher heterotic hybrids from the segregating population. Earlier workers like (7), (3), (4) and (6) have also indicated the significance of genetic divergence.

## CONCLUSION

There was wide range of variations in radish genotypes for all the characters. Genetic divergence gives an idea about the scope of improvement in a character through simple selection and hybridization. Genetic divergence in twenty genotype of radish was grouped in five clusters. The resultant five clusters had showed wider genetic diversity and maximum number of genotypes was accommodated in III and V. The maximum intra cluster distance was found in cluster I and the highest inter cluster distance was recorded between cluster I and cluster IV indicated that genotypes included in these clusters can be used as parents in hybridization programme to get higher heterotic hybrids from the segregating populations.

**Table.1 Mean Performance of twenty two genotypes for the characters under study Radish**

| S.No. | Genotypes                   | LWP   | NOL   | RWWL   | RWWL   | LW     | RL    | LL    | RD   | AA    | DMC  | TSS  | RYPP |
|-------|-----------------------------|-------|-------|--------|--------|--------|-------|-------|------|-------|------|------|------|
| 1     | Japanese White              | 62.17 | 15.47 | 360.67 | 244.67 | 116.00 | 28.65 | 32.32 | 2.87 | 13.40 | 7.26 | 5.02 | 2.04 |
| 2     | Pusa Himani                 | 58.18 | 13.00 | 270.67 | 182.07 | 88.60  | 32.26 | 25.92 | 3.03 | 13.67 | 7.16 | 5.11 | 1.76 |
| 3     | White Icicle                | 57.94 | 7.13  | 153.92 | 116.31 | 37.60  | 32.55 | 25.75 | 2.63 | 19.47 | 7.18 | 6.40 | 1.24 |
| 4     | Radish Red White Tipped     | 37.03 | 9.47  | 151.25 | 163.20 | 46.93  | 12.13 | 25.23 | 4.45 | 21.09 | 6.68 | 6.45 | 1.11 |
| 5     | Pusa Chetki                 | 62.63 | 11.67 | 309.56 | 104.32 | 95.33  | 24.07 | 38.68 | 3.07 | 14.35 | 9.08 | 5.70 | 2.02 |
| 6     | Local Collection, Bageshwar | 62.82 | 16.67 | 327.33 | 233.00 | 94.33  | 32.97 | 29.85 | 2.75 | 15.27 | 7.22 | 5.81 | 2.02 |
| 7     | Local Collection (Bharsar)  | 60.83 | 14.20 | 345.00 | 273.93 | 98.67  | 27.75 | 32.91 | 2.64 | 14.43 | 7.46 | 6.00 | 1.73 |
| 8     | Mino Early White            | 63.93 | 14.47 | 382.33 | 251.47 | 126.40 | 32.59 | 31.33 | 3.41 | 14.87 | 7.44 | 5.89 | 2.17 |
| 9     | Lambi Vilayti               | 68.96 | 13.00 | 332.33 | 194.67 | 138.00 | 26.18 | 42.78 | 3.53 | 13.47 | 7.16 | 5.08 | 1.89 |
| 10    | 40 Days                     | 53.35 | 10.80 | 256.00 | 154.00 | 101.33 | 22.17 | 31.17 | 2.26 | 15.75 | 8.13 | 4.88 | 1.39 |
| 11    | Chandani                    | 50.67 | 12.33 | 252.33 | 113.00 | 139.33 | 24.55 | 25.99 | 2.63 | 20.67 | 8.75 | 6.23 | 1.11 |
| 12    | Arka Nishant                | 70.69 | 11.00 | 239.13 | 153.33 | 86.13  | 24.71 | 45.99 | 3.43 | 17.51 | 8.12 | 5.71 | 1.43 |
| 13    | Hill Queen                  | 56.14 | 14.40 | 332.00 | 229.33 | 102.89 | 29.05 | 28.25 | 3.62 | 16.41 | 7.30 | 5.84 | 2.06 |
| 14    | Chetki Long                 | 58.04 | 14.07 | 257.67 | 162.00 | 94.33  | 25.57 | 32.72 | 2.36 | 13.71 | 8.09 | 7.06 | 1.56 |
| 15    | Ganga                       | 64.27 | 13.13 | 365.00 | 236.67 | 128.33 | 27.74 | 36.53 | 2.59 | 15.47 | 5.45 | 6.07 | 1.83 |
| 16    | Gol Mulli                   | 73.22 | 16.73 | 394.47 | 277.13 | 117.33 | 34.35 | 38.89 | 5.17 | 14.88 | 8.07 | 5.82 | 2.21 |
| 17    | Agri Long White             | 47.83 | 8.87  | 156.53 | 97.27  | 55.93  | 19.44 | 28.39 | 2.15 | 18.40 | 7.11 | 5.28 | 1.01 |
| 18    | Radish Roshni               | 58.98 | 12.73 | 345.00 | 247.87 | 97.13  | 29.25 | 29.74 | 2.39 | 12.46 | 6.45 | 5.04 | 2.47 |
| 19    | Local Collection, Nainital  | 57.69 | 13.33 | 221.33 | 137.62 | 83.71  | 27.65 | 30.04 | 2.14 | 15.62 | 6.84 | 5.20 | 1.19 |
| 20    | Radish Rupali               | 60.68 | 12.60 | 262.53 | 160.73 | 101.80 | 25.03 | 35.52 | 2.21 | 20.46 | 6.48 | 5.81 | 1.52 |
|       | Mean                        | 59.30 | 12.75 | 285.75 | 186.63 | 97.51  | 26.93 | 32.40 | 2.97 | 16.07 | 7.37 | 5.72 | 1.69 |
|       | Max                         | 37.03 | 7.13  | 151.25 | 97.27  | 37.60  | 12.13 | 25.23 | 2.14 | 12.46 | 5.45 | 4.88 | 1.01 |
|       | Min                         | 73.22 | 16.73 | 394.47 | 277.13 | 139.33 | 34.35 | 45.99 | 5.17 | 21.09 | 9.08 | 7.06 | 2.47 |
|       | SE(d)                       | 1.01  | 0.52  | 4.90   | 4.30   | 2.31   | 0.76  | 1.11  | 0.05 | 0.06  | 0.06 | 0.32 | 0.12 |
|       | C.D. at 5%                  | 2.05  | 1.05  | 9.96   | 8.73   | 4.69   | 1.55  | 2.25  | 0.11 | 0.11  | 0.12 | 0.64 | 0.25 |
|       | C.V. (%)                    | 2.08  | 4.97  | 2.10   | 2.82   | 2.90   | 3.47  | 4.18  | 2.24 | 0.42  | 0.99 | 6.77 | 8.82 |

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

LWP = Length of whole plant after harvesting (cm), NOL= Number of leaves, RWWL= Root weight with leaves (g), RWWL = Root weight without leaves (g), LW= Leaves weight (g), RL= Root length (cm), LL = Leaf length (cm), RD= Root diameter (cm), AA= Ascorbic acid (mg/100g), DMC= Dry matter content (g), TSS= Total soluble solids (°B) and RYYP= Root yield per plot (kg).

**Table 2: Average inter and intra cluster distance (D2)**

| Clusters | I     | II    | III   | IV    | V     |
|----------|-------|-------|-------|-------|-------|
| I        | 2.643 |       |       |       |       |
| II       | 4.918 | 2.138 |       |       |       |
| III      | 3.661 | 2.909 | 2.155 |       |       |
| IV       | 8.606 | 5.208 | 6.508 | 1.121 |       |
| V        | 5.959 | 3.400 | 3.434 | 4.036 | 1.972 |

**Table 3: Cluster mean for different characters among twenty genotypes of radish**

| Traits |      | LWP   | NOL   | RWWL   | RWWL   | LW     | RL    | LL    | RD   | AA    | DMC  | TSS  | RYYP |
|--------|------|-------|-------|--------|--------|--------|-------|-------|------|-------|------|------|------|
| I      | Mean | 47.60 | 8.49  | 153.90 | 125.59 | 46.82  | 21.37 | 26.46 | 3.08 | 19.65 | 6.99 | 6.05 | 1.12 |
| II     | Mean | 63.79 | 12.24 | 268.79 | 139.88 | 91.93  | 24.78 | 39.13 | 2.96 | 15.19 | 8.43 | 6.15 | 1.67 |
| III    | Mean | 55.60 | 12.27 | 248.05 | 141.34 | 106.54 | 24.85 | 30.68 | 2.31 | 18.13 | 7.55 | 5.53 | 1.30 |
| IV     | Mean | 73.22 | 16.73 | 394.47 | 277.13 | 117.33 | 34.35 | 38.89 | 5.17 | 14.88 | 8.07 | 5.82 | 2.21 |
| V      | Mean | 61.81 | 14.12 | 340.04 | 232.63 | 110.04 | 29.60 | 32.18 | 2.98 | 14.38 | 6.99 | 5.54 | 2.00 |

LWP = Length of whole plant after harvesting (cm), NOL= Number of leaves, RWWL= Root weight with leaves (g), RWWL = Root weight without leaves (g), LW= Leaves weight (g), RL= Root length (cm), LL = Leaf length (cm), RD= Root diameter (cm), AA= Ascorbic acid (mg/100g), DMC= Dry matter content (g), TSS= Total soluble solids (°B) and RYYP= Root yield per plot (kg).

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## ESTIMATION OF CORRELATION AND PATH COEFFICIENT STUDIES IN TOMATO (*LYCOPERSICON ESCULENTUM* MILL.)

Sharifullah Rahimi\*, Bijendra Singh, Khursheed Alam,

Vipin Kumar and Muzeev Ahmad

Department of Horticulture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut

\*Corresponding Author E-mail– [alamk1996@gmail.com](mailto:alamk1996@gmail.com)

### ABSTRACT

The present investigation was conducted at Horticulture Research Centre, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, U.P. during Kharif season, 2020. The experimental material comprised of twenty genotypes were planted in Randomized Block Design with three replications. Fruit yield per hectare showed positive and highly significant correlation with fruit yield per plant, number of fruits per plant, harvest duration, 1000 seeds weight, number of seeds per fruit, number of fruits per cluster and number of clusters per plant at both genotypic and phenotypic correlation. Positive and non-significant correlation for plant height, average fruit weight, number of locules per fruit and number of primary branches. Path coefficient analysis revealed that the highest positive direct effect on yield per hectare was observed for fruit yield per plant, number of seeds per fruit, number of fruits per cluster, harvest duration and 1000 seed weight. Hence these traits may be simultaneously selected to develop high yielding varieties.

**Keywords:** Tomato, *Lycopersicon esculentum*, Correlation, Path-coefficient

### INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most economically important vegetable crop belong to the family Solanaceae with diploid chromosome number  $2n=24$ . It is universally treated as “protective food” due to its special value and widespread production. It is native of Peru Ecuador Bolivia Region of Andes, South America Rick (1969). The genus *Lycopersicon* consists of annual and short-lived perennial herbaceous plants. It is a typical day-neutral plant and is mainly self-pollinated, but a certain percentage of cross-pollination also occurs. Tomato is a warm-season crop reasonably resistant to heat, drought and grows under a wide range of soil and climatic conditions. Tomato is cultivated in India with 778 thousand

hectares in area with production of 19397 thousand Metric tons (1). Andhra Pradesh is the leading tomato producing state with production of around 2744.32 thousand Metric tons from an area of 61.67 thousand hectare.

### MATERIALS AND METHODS

The present investigations were conducted at Horticulture Research Centre, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, U.P. during Kharif season, 2020. The experimental material comprised of twenty genotypes with twelve characters of tomato and the experiment was laid out in randomized block design with three replications. The seedlings were transplanted in a randomized block design with three replications at the spacing of 90 cm. between

rows and 30 cm between plant to plant. The net plot size of  $2.25 \times 1.80$  meter was kept for each genotype. All the recommended cultural practices and plant protection measures were followed. Data were recorded for twelve characters *viz.*, number of primary branches, plant height (cm), number of fruits per cluster, number of clusters per plant, number of fruits per plant, number of locules per fruit, harvest duration (days), average fruit weight (g), fruit yield per plant (g), fruit yield per hectare (q), number of seeds per fruits and 1000 seed weight (g).

## **RESULTS AND DISCUSSION**

### **Correlation Coefficient Analysis**

Correlation coefficient studies indicated that genotypic correlation coefficient was found to be higher than phenotypic correlation coefficients for most of the characters, indicating a strong inherent association between various characters and significantly affected by environmental factors in regard to phenotypic expression. Also, small variation between phenotypic and genotypic correlation coefficient was noticed for almost all the pairs of traits studied showing that masking or modifying effects of the environment was little indicating the presence of an inherent association among these traits. Estimation of phenotypic and genotypic correlation coefficient of traits is presented in (Table-1 & 2). Fruit yield per hectare showed positive and highly significant correlation with fruit yield per plant (0.987 & 0.959), number of fruits per plant (0.602 & 0.571), harvest duration (0.569 & 0.514), 1000 seeds weight (0.447 & 0.396), number of seeds per fruit (0.437 & 0.394),

number of fruits per cluster (0.409 & 0.343) and number of clusters per plant (0.343 & 0.304). It also reported positive and non-significant correlation for plant height (0.213 & 0.191), average fruit weight (0.213 & 0.217), number of locules per fruit (0.109 & 0.078) and number of primary branches (0.065 & 0.051) at both genotypic and phenotypic level. Thus, it can be inferred that selection based on any one of these characters either alone or in combination, will result in identifying high yielding strains. These results were close in conformity with findings of (8, 9, 14, 12, 6).

### **Path Coefficient Analysis**

Path coefficient analysis is a powerful tool, which enable portioning of the given relationships in its further components. In other words, it takes into account not only the relationship of component characters with the dependent character, but simultaneously takes care of its relationship with another component also. Thus, it helps in understanding the causal system in a better way because it enables portioning the total correlations coefficient into direct and indirect effects of various traits. The results obtained at genotypic and phenotypic levels of path coefficient are presented in (Table-3 & 4). The highest positive direct effect on yield per hectare was observed for fruit yield per plant (0.987 & 0.959), number of fruits per plant (0.437 & 0.571), harvest duration (0.569 & 0.514), 1000 seeds weight (0.447 & 0.396), number of seed per fruit (0.437 & 0.394) and number of fruits per cluster (0.409 & 0.343) at both genotypic and phenotypic path coefficient. Fruit yield per hectare could be improved by selection based on fruit yield per plant. The direct effect of remaining characters on fruit yield per hectare were of low magnitude. These results are in general agreement with the findings of by (2, 10, 5, 7, 3).

**Table-1. Estimates of correlation coefficient at genotypic levels in Tomato**

| Characters                   | Number of primary branches | Plant height (cm) | Number of fruits per cluster | Number of clusters per plant | Number of fruits per plant | Number of locules per fruit | Harvest duration (days) | Average fruit weight (g) | Number of seeds per fruits | 1000 seed weight (g) | Fruit yield per plant (g) | Fruit yield /hectare (q) |
|------------------------------|----------------------------|-------------------|------------------------------|------------------------------|----------------------------|-----------------------------|-------------------------|--------------------------|----------------------------|----------------------|---------------------------|--------------------------|
| Number of primary branches   | 1.000                      | 0.162             | 0.340*                       | -0.419*                      | 0.056                      | -0.062                      | -0.209                  | 0.201                    | -0.039                     | -0.100               | 0.049                     | 0.065                    |
| Plant height (cm)            |                            |                   | 0.337*                       | -0.056                       | 0.097                      | -0.187                      | -0.055                  | 0.202                    | 0.272*                     | -0.001               | 0.208                     | 0.213                    |
| Number of fruits per cluster |                            |                   |                              | -0.266*                      | 0.504*                     | -0.239                      | -0.135                  | -0.037                   | 0.091                      | 0.542*               | 0.356*                    | 0.409*                   |
| Number of clusters per plant |                            |                   |                              |                              | 0.674*                     | 0.404*                      | 0.436*                  | -0.575*                  | -0.297*                    | -0.074               | 0.316*                    | 0.343*                   |
| Number of fruits per plant   |                            |                   |                              |                              |                            | 0.227                       | 0.306*                  | -0.583*                  | -0.263*                    | 0.257*               | 0.545*                    | 0.602*                   |
| Number of locules per fruit  |                            |                   |                              |                              |                            |                             | 0.325*                  | -0.268*                  | -0.036                     | 0.138                | 0.099                     | 0.109                    |
| Harvest duration (days)      |                            |                   |                              |                              |                            |                             |                         | 0.110                    | 0.482*                     | 0.063                | 0.569*                    | 0.569*                   |
| Average fruit weight (g)     |                            |                   |                              |                              |                            |                             |                         |                          | 0.850*                     | 0.175                | 0.252                     | 0.213                    |
| Number of seeds per fruit    |                            |                   |                              |                              |                            |                             |                         |                          |                            | 0.313*               | 0.447*                    | 0.437*                   |
| 1000 seed weight (g)         |                            |                   |                              |                              |                            |                             |                         |                          |                            |                      | 0.420*                    | 0.447*                   |
| Fruit yield per plant (g)    |                            |                   |                              |                              |                            |                             |                         |                          |                            |                      |                           | 0.987*                   |
| Fruit yield /hectare (q)     |                            |                   |                              |                              |                            |                             |                         |                          |                            |                      |                           | 1.000                    |

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

**Table-2. Estimates of correlation coefficient at phenotypic levels in Tomato**

| Characters                   | Number of primary branches | Plant height (cm) | Number of fruits per cluster | Number of clusters per plant | Number of fruits per plant | Number of locules per fruit | Harvest duration (days) | Average fruit weight (g) | Number of seeds per fruits | 1000 seed weight (g) | Fruit yield per plant (g) | Fruit yield /hectare (q) |
|------------------------------|----------------------------|-------------------|------------------------------|------------------------------|----------------------------|-----------------------------|-------------------------|--------------------------|----------------------------|----------------------|---------------------------|--------------------------|
| Number of primary branches   | 1.000                      | 0.101             | 0.219                        | -0.339*                      | 0.027                      | -0.101                      | -0.147                  | 0.180                    | -0.042                     | -0.067               | 0.047                     | 0.051                    |
| Plant height (cm)            |                            |                   | 0.241                        | -0.037                       | 0.076                      | -0.149                      | -0.058                  | 0.190                    | 0.269*                     | 0.004                | 0.193                     | 0.191                    |
| Number of fruits per cluster |                            |                   |                              | -0.234                       | 0.423*                     | -0.180                      | -0.144                  | -0.019                   | 0.091                      | 0.402*               | 0.328*                    | 0.343*                   |
| Number of clusters per plant |                            |                   |                              |                              | 0.636*                     | 0.340*                      | 0.394*                  | -0.545*                  | -0.277*                    | -0.047               | 0.287*                    | 0.304*                   |
| Number of fruits per plant   |                            |                   |                              |                              |                            | 0.202                       | 0.294*                  | -0.560*                  | -0.258*                    | 0.242                | 0.531*                    | 0.571*                   |

|                             |  |  |  |  |  |  |        |        |        |        |        |        |
|-----------------------------|--|--|--|--|--|--|--------|--------|--------|--------|--------|--------|
| Number of locules per fruit |  |  |  |  |  |  | 0.289* | -0.234 | -0.033 | 0.084  | 0.079  | 0.078  |
| Harvest duration (days)     |  |  |  |  |  |  |        | 0.087  | 0.442* | 0.045  | 0.536* | 0.514* |
| Average fruit weight (g)    |  |  |  |  |  |  |        |        | 0.815* | 0.147  | 0.253  | 0.217  |
| Number of seeds per fruit   |  |  |  |  |  |  |        |        |        | 0.276* | 0.432* | 0.394* |
| 1000 seed weight (g)        |  |  |  |  |  |  |        |        |        |        | 0.388* | 0.396* |
| Fruit yield per plant (g)   |  |  |  |  |  |  |        |        |        |        |        | 0.959* |
| Fruit yield /hectare (q)    |  |  |  |  |  |  |        |        |        |        |        | 1.000  |

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

**Table-3. Path coefficient analysis at genotypic levels on fruit yield per hectare in Tomato**

| Characters                   | Number of primary branches | Plant height (cm) | Number of fruits per cluster | Number of clusters per plant | Number of fruits per plant | Number of locules per fruit | Harvest duration (days) | Average fruit weight (g) | Fruit yield per plant (g) | Number of seeds per fruits | 1000 seed weight (g) | Fruit yield /ha (q) |
|------------------------------|----------------------------|-------------------|------------------------------|------------------------------|----------------------------|-----------------------------|-------------------------|--------------------------|---------------------------|----------------------------|----------------------|---------------------|
| Number of primary branches   | -0.0872                    | 0.0056            | -0.0993                      | 0.1497                       | 0.0313                     | -0.0001                     | 0.0104                  | 0.0136                   | 0.0447                    | -0.0017                    | -0.0022              | 0.065               |
| Plant height (cm)            | -0.0142                    | 0.0343            | -0.0985                      | 0.0201                       | 0.0537                     | -0.0002                     | 0.0028                  | 0.0137                   | 0.1898                    | 0.0117                     | 0.0000               | 0.213               |
| Number of fruits per cluster | -0.0296                    | 0.0116            | -0.2924                      | 0.0950                       | 0.2796                     | -0.0003                     | 0.0068                  | -0.0025                  | 0.3249                    | 0.0039                     | 0.0120               | 0.409**             |
| Number of clusters per plant | 0.0366                     | -0.0019           | 0.0778                       | -0.3570                      | 0.3742                     | 0.0005                      | -0.0218                 | -0.0390                  | 0.2880                    | -0.0128                    | -0.0017              | 0.343**             |
| Number of fruits per plant   | -0.0049                    | 0.0033            | -0.1473                      | -0.2407                      | 0.5550                     | 0.0003                      | -0.0153                 | -0.0396                  | 0.4967                    | -0.0113                    | 0.0057               | 0.602**             |
| Number of locules per fruit  | 0.0054                     | -0.0064           | 0.0700                       | -0.1444                      | 0.1257                     | 0.0013                      | -0.0162                 | -0.0182                  | 0.0900                    | -0.0016                    | 0.0031               | 0.109               |
| Harvest duration (days)      | 0.0183                     | -0.0019           | 0.0396                       | -0.1558                      | 0.1699                     | 0.0004                      | -0.0499                 | 0.0075                   | 0.5188                    | 0.0208                     | 0.0014               | 0.569**             |
| Average fruit weight (g)     | -0.0176                    | 0.0069            | 0.0107                       | 0.2051                       | -0.3238                    | -0.0003                     | -0.0055                 | 0.0678                   | 0.2296                    | 0.0366                     | 0.0039               | 0.213               |
| Fruit yield per plant (g)    | -0.0043                    | 0.0071            | -0.1042                      | -0.1127                      | 0.3023                     | 0.0001                      | -0.0284                 | 0.0171                   | 0.9120                    | 0.0192                     | 0.0093               | 0.987**             |
| Number of seeds /fruits      | 0.0034                     | 0.0093            | -0.0265                      | 0.1060                       | -0.1460                    | -0.0001                     | -0.0240                 | 0.0576                   | 0.4072                    | 0.0431                     | 0.0069               | 0.437**             |
| 1000 seed weight (g)         | 0.0087                     | 0.0000            | -0.1586                      | 0.0266                       | 0.1428                     | 0.0002                      | -0.0031                 | 0.0119                   | 0.3829                    | 0.0135                     | 0.0222               | 0.447**             |

Resi = 0.0367

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

**Table-4. Path coefficient analysis at phenotypic levels on fruit yield per hectare in Tomato**

| Characters                   | Number of primary branches | Plant height (cm) | Number of fruits per cluster | Number of clusters per plant | Number of fruits per plant | Number of locules per fruit | Harvest duration (days) | Average fruit weight (g) | Fruit yield per plant (g) | Number of seeds per fruits | 1000 seed weight (g) | Fruit yield /ha (q) |
|------------------------------|----------------------------|-------------------|------------------------------|------------------------------|----------------------------|-----------------------------|-------------------------|--------------------------|---------------------------|----------------------------|----------------------|---------------------|
| Number of primary branches   | -0.0360                    | 0.0012            | -0.0015                      | 0.0040                       | 0.0069                     | -0.0005                     | -0.0065                 | 0.0440                   | 0.0364                    | 0.0046                     | -0.0016              | 0.0510              |
| Plant height (cm)            | -0.0036                    | 0.0117            | -0.0017                      | 0.0004                       | 0.0194                     | -0.0008                     | -0.0026                 | 0.0464                   | 0.1511                    | -0.0297                    | 0.0001               | 0.1910              |
| Number of fruits per cluster | -0.0079                    | 0.0028            | -0.0069                      | 0.0028                       | 0.1082                     | -0.0009                     | -0.0064                 | -0.0045                  | 0.2561                    | -0.0100                    | 0.0094               | 0.343**             |
| Number of clusters per plant | 0.0122                     | -0.0004           | 0.0016                       | -0.0119                      | 0.1624                     | 0.0017                      | 0.0174                  | -0.1334                  | 0.2244                    | 0.0306                     | -0.0011              | 0.304*              |
| Number of fruits per plant   | -0.0010                    | 0.0009            | -0.0029                      | -0.0075                      | 0.2555                     | 0.0010                      | 0.0130                  | -0.1369                  | 0.4148                    | 0.0285                     | 0.0056               | 0.571**             |
| Number of locules per fruit  | 0.0036                     | -0.0018           | 0.0012                       | -0.0040                      | 0.0516                     | 0.0050                      | 0.0128                  | -0.0573                  | 0.0615                    | 0.0037                     | 0.0020               | 0.0780              |
| Harvest duration (days)      | 0.0053                     | -0.0007           | 0.0010                       | -0.0047                      | 0.0752                     | 0.0015                      | 0.0442                  | 0.0214                   | 0.4186                    | -0.0488                    | 0.0011               | 0.514**             |
| Average fruit weight (g)     | -0.0065                    | 0.0022            | 0.0001                       | 0.0065                       | -0.1430                    | -0.0012                     | 0.0039                  | 0.2445                   | 0.1973                    | -0.0899                    | 0.0034               | 0.2170              |
| Fruit yield per plant (g)    | -0.0017                    | 0.0023            | -0.0023                      | -0.0034                      | 0.1356                     | 0.0004                      | 0.0237                  | 0.0618                   | 0.7814                    | -0.0476                    | 0.0090               | 0.959**             |
| Number of seeds /fruits      | 0.0015                     | 0.0032            | -0.0006                      | 0.0033                       | -0.0660                    | -0.0002                     | 0.0196                  | 0.1994                   | 0.3373                    | -0.1103                    | 0.0064               | 0.394**             |
| 1000 seed weight (g)         | 0.0024                     | 0.0001            | -0.0028                      | 0.0006                       | 0.0617                     | 0.0004                      | 0.0020                  | 0.0359                   | 0.3030                    | -0.0305                    | 0.0233               | 0.396**             |

Resi = 0.0680

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

## CONCLUSION

Correlation and path coefficient analysis, fruit yield per plant, number of fruits per plant and fruit yield per hectare would be considered as the reliable selection parameters for developing high yielding genotypes.

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## STUDIES ON GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE AMONG THE CHARACTERS OF TOMATO (*LYCOPERSICON ESCULENTUM* MILL.)

Sharifullah Rahimi<sup>1\*</sup>, Bijendra Singh<sup>2</sup>, Vipin Kuamr<sup>3</sup>, L.K. Gangwar<sup>4</sup>  
Khursheed Alam<sup>5</sup>, Shalini Gupta<sup>6</sup> and Muzeev Ahmad<sup>7</sup>

<sup>1,2,3,5,7</sup>Department. of Horticulture, SVPUA&T, Meerut

<sup>4</sup>Deptment. of Genetics and Plant Breeding, SVPUA&T, Meerut

<sup>6</sup>Department of Agriculture Biotechnology, SVPUA&T, Meerut

\*Corresponding Author E-mail– [alamk1996@gmail.com](mailto:alamk1996@gmail.com)

### ABSTRACT

Twenty tomato genotypes were evaluated to genetic variability, heritability and genetic advance among the characters of tomato (*Lycopersicon esculentum* Mill). The genotypes were planted in Randomized Block Design with three replications during the Kharif season- 2020 at Horticulture Research centre, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, U.P. (250 110). The analysis of variance revealed high significant differences among the genotypes for all the characters under studies, suggesting sufficient variability for yield and yield contributing characters. The phenotypic coefficient of variations (PCV) was higher than the genotypic coefficients of variations (GCV) for all traits studied. The maximum phenotypic and genotypic coefficient (PCV and GCV) was observed for number of fruits per plant (38.11 & 37.57), number of clusters per plant (36.17 & 34.72), number of locules per fruit (33.23 & 29.99), number of seeds per fruit (31.71 & 31.25), fruit yield per hectare (26.76 & 25.28) and fruit yield per plant (26.23 & 25.45). Heritability estimates varied from (60.97) number of fruits per cluster to (97.19) number of fruits per plant. genetic advance expressed as percentage of mean was high (>20%) for number of fruits per plant (76.30), number of clusters per plant (68.65), number of seeds per fruit (63.46), number of locules per fruit (55.77), fruit yield per plant (50.85), fruit yield per hectare (49.21), average fruit weight (42.96), 1000 seeds weight (32.87), harvest duration (31.25), number of primary branches (29.07), plant height (28.39) and minimum for fruits per cluster (26.76) indicating the additive genetic effect. Phenotypic selection for their improvement could be achieved by simple selection.

**Keywords:** Genetic advance, Heritability, Tomato, Variability

### INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important, popular and extensively used vegetable crop of the Solanaceae family which includes other well-known species, such as potato, tobacco, peppers and egg-plant (aubergine) (Olmstead *et al.*, 2008). Tomato has originated in the

South American Andes. The cultivated tomato was introduced to Europe by the Spanish conquistadors in the 16<sup>th</sup> century and later introduced from Europe to southern and eastern Asia, Africa and the Middle East. The wild type of tomato has been distributed into other parts of South America and Mexico. Tomatoes contribute to a healthy,

well-balanced diet. it is rich source of minerals, vitamins, essential amino acids, sugars and dietary fibres. Tomato contains a lot of vitamin B and C, iron and phosphorus. Tomato fruits are consumed fresh in salads or cooked in sauces, soup, meat and fish dishes. Tomato can be processed into purées, juices and ketchup. Canned and dried tomatoes are economically very important processed products. The development of successful plant breeding programme is depending upon the assessment of polygenic variation, selection of elite genotypes, choice of parents and breeding procedures. Crop improvement depends upon the magnitude of genetic variability and measure the desirable characters of heritable. Genetic variability for yield and yield components is essential in the base population for successful crop development (Allard *et. al.*, 1960).

## MATERIALS AND METHODS

An experiment consists of 20 diverse genotypes and twelve characters of Tomato (*Lycopersicon esculentum* Mill.) was conducted at Horticultural Research Centre, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut during Kharif season-2020 in Randomized Block Design (RBD) with three replications. The genotypes were diverse for morphological and important economical traits. The genotypes were grown with a spacing of 90 cm × 30 cm. The experiment was grown with a standard package of practices. The observations on various growth, yield, and qualitative characters were recorded and observed highly significant differences for all the characters under study.

## RESULTS AND DISCUSSION

The analysis of variance (Table-4.1) for twenty genotypes of tomato revealed significant difference for all the 12 characters *viz.*, number of primary branches

(2.05), plant height (cm) (435.36), number of fruits per cluster (1.90), number of clusters per plant (17.28), number of fruits per plant (38307), number of locules per fruit (4.88), harvest duration (days) (100.44), average fruit weight (g) (231.61), fruit yield per plant (g) (263301.78), fruit yield per hectare (q) (28922.64), number of seeds per fruits (1823.42) and 1000 seed weight (g) (0.80). Therefore, the present study showed a wide range of phenotypic and highly significant varietal differences were found among the genotypes for all the traits indicating considerable amount of variability and providing ample scope for selecting the desirable types. Similar findings for most of the characters were also obtained by (12, 3, 2, 4, 17, 9). In the present investigation mean performance (Table-4.2) were found significantly different for all the traits *viz.*, maximum number of primary branches was showed in VRT-51 (6.0) and minimum number of primary branches was observed in ToLCV-16 (2.67). The germplasm VRT-1 had maximum plant height of (101.00 cm) whereas, Kashi Hemant had minimum plant height (60.00 cm). The genotype VRT-67 had maximum number of fruits per cluster (6.00), while the lowest number of fruits per cluster observed in genotype ToLCV-16 (2.67). The germplasm ToLCV-16 had maximum number of clusters per plant (11.67), while the germplasm VRT-1 had minimum number of clusters per plant (03.33). The maximum number of fruits per plant was observed in VRT-67 (67.67), while minimum number of fruits per plant was observed in Pusa Ruby (19.00). The maximum number of locules per fruit was observed in Kashi Hemant (7.00), while minimum number of locules per fruit was observed in VRT-34 (2.33). The maximum harvest duration in germplasm H-24 (47.33) whereas, the minimum harvest duration was observed in VRT-16-1 (26.67). The genotype Pusa Ruby was observed maximum fruit weight (53.33), while the minimum fruit weight was recorded in VRT-67

(20.00). The maximum fruit yield per plant was observed in germplasm ToLCV-28 (1843.33) whereas, the minimum fruit yield was recorded in VRT-2 (p.c) (552.67). The maximum fruit yield per hectare was recorded in ToLCV-28 germplasm (608.30), while minimum fruit yield per hectare was observed in VRT-2 (p.c) (182.38). The maximum number of seeds per fruit was observed in cultivar H-24 (123.33) whereas, the minimum number of seeds per fruit in VRT-67 (45.33). The maximum 1000 seed weight was recorded in germplasm VRT-13 (4.10), while the minimum 1000 seed weight was observed in VRT-50 (2.27) had showed significant difference indicating sufficient genetic variability. The mean for fruit yield q/ha was higher in the genotype ToLCV-28 (608.30 q/ha). thus, it is implying that were ample variability in the genotypes of tomato. The result was also found earlier by (24, 8, 11, 22, 7, 5).

The phenotypic coefficient of variations (PCV) was higher than the genotypic coefficients of variations (GCV) for all traits studied in Table-4.3. The estimates of phenotypic coefficient of variation (PCV) for different characters. The phenotypic coefficient of variation (>25%) was observed number of fruits per plant (38.11), number of clusters per plant (36.17), number of locules per fruit (33.23), number of seeds per fruit (31.71), fruit yield per hectare (26.76) and fruit

yield per plant (26.23). The moderate phenotypic coefficient of variation (10-25%) was observed for average fruit weight (22.32), number of fruits per cluster (21.30), number of primary branches (20.71), 1000 seeds weight (17.93), harvest duration (16.62) and plant height (15.00). Similar result was also found earlier by (12, 3, 2, 13, 23, 15, 10, 22, 18).

High heritability (Table-4.3) (>60%) was obtained for number of fruits per plant (97.19), number of seeds per fruit (97.15), fruit yield per plant (94.11), average fruit weight (93.42), number of clusters per plant (92.15), plant height (91.91), harvest duration (91.25), fruit yield per hectare (89.26), 1000 seeds weight (89.02), number of locules per fruit (81.47), number of primary branches (68.12) and number of fruits per cluster (60.97). Similar result was also reported earlier by (20, 16, 21, 11, 10, 7, 5).

The highest genetic advance as percentage of mean (Table-4.3) was (>20%) for number of fruits per plant (76.30), number of clusters per plant (68.65), number of seeds per fruit (63.46), number of locules per fruit (55.77), fruit yield per plant (50.85), fruit yield per hectare (49.21), average fruit weight (42.96), 1000 seeds weight (32.87), harvest duration (31.25), number of primary branches (29.07), plant height (28.39) and minimum for fruits per cluster (26.76). Similar result was also found earlier by (3, 6, 9, 4, 11, 10, 7, 5)

Table-4.1. ANOVA for 12 characters in Tomato (*Lycopersicum esculentum*)

| Source of Variation | DF | Number of primary branches | Plant height (cm) | Number of fruits per cluster | Number of clusters per plant | Number of fruits per plant | Number of locules per fruit |
|---------------------|----|----------------------------|-------------------|------------------------------|------------------------------|----------------------------|-----------------------------|
| Replication         | 2  | 0.24                       | 14.52             | 0.11                         | 1.27                         | 14.32                      | 0.80                        |
| Treatment           | 19 | 2.05**                     | 435.36**          | 1.90**                       | 17.28**                      | 383.07**                   | 4.88**                      |
| Error               | 38 | 0.28                       | 12.41             | 0.33                         | 0.48                         | 3.65                       | 0.34                        |

| Source of Variation | DF | Harvest duration (days) | Average fruit weight (g) | Fruit yield per plant (g) | Fruit yield /hactare (q) | Number of seeds per fruits | 1000 seed weight (g) |
|---------------------|----|-------------------------|--------------------------|---------------------------|--------------------------|----------------------------|----------------------|
| Replication         | 2  | 10.22                   | 9.45                     | 13171.62                  | 6440.73                  | 98.75                      | 0.05                 |
| Treatment           | 19 | 100.44**                | 231.61**                 | 263301.78**               | 28922.64**               | 1823.42**                  | 0.80**               |
| Error               | 38 | 3.11                    | 5.31                     | 5385.34                   | 1114.83                  | 17.64                      | 0.03                 |

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

Table-4.2. Mean performance of 20 genotypes of Tomato for 12 characters

| S.N o. | Genotypes    | Number of primary branches | Plant height (cm) | Number of fruits per cluster | Number of clusters per plant | Number of fruits per plant | Number of locules per fruit | Harvest duration (days) | Average fruit weight (g) | Fruit yield per plant (g) | Fruit yield /ha (q) | Number of seeds per fruits | 1000 seed weight (g) |
|--------|--------------|----------------------------|-------------------|------------------------------|------------------------------|----------------------------|-----------------------------|-------------------------|--------------------------|---------------------------|---------------------|----------------------------|----------------------|
| 1      | Pusa Ruby    | 5.00                       | 63.00             | 3.33                         | 5.00                         | 19.00                      | 3.67                        | 41.33                   | 53.33                    | 1013.00                   | 334.29              | 111.00                     | 2.67                 |
| 2      | Kashi Hemant | 4.00                       | 60.00             | 4.33                         | 6.00                         | 27.33                      | 7.00                        | 33.00                   | 32.33                    | 884.00                    | 291.72              | 55.67                      | 3.37                 |
| 3      | VRT-51       | 6.00                       | 89.33             | 3.67                         | 5.33                         | 22.00                      | 3.67                        | 30.67                   | 43.33                    | 952.00                    | 314.16              | 61.67                      | 2.70                 |
| 4      | VRT-67       | 5.33                       | 83.33             | 6.00                         | 11.00                        | 67.67                      | 4.67                        | 35.67                   | 20.00                    | 1336.00                   | 440.88              | 45.33                      | 3.37                 |
| 5      | Sel-7        | 4.00                       | 61.00             | 3.33                         | 9.33                         | 31.33                      | 4.00                        | 34.00                   | 37.67                    | 1307.33                   | 431.30              | 59.33                      | 2.53                 |
| 6      | VRT-19       | 5.00                       | 94.00             | 4.67                         | 5.67                         | 28.33                      | 4.33                        | 32.00                   | 36.00                    | 999.33                    | 329.78              | 67.67                      | 2.33                 |
| 7      | VRT-06       | 3.00                       | 92.33             | 3.67                         | 9.67                         | 37.00                      | 3.00                        | 38.00                   | 30.00                    | 1108.00                   | 365.64              | 58.00                      | 2.60                 |
| 8      | VRT-50       | 5.67                       | 96.33             | 4.67                         | 4.33                         | 21.33                      | 2.33                        | 28.33                   | 50.00                    | 1069.33                   | 353.06              | 84.33                      | 2.27                 |
| 9      | VRT-30       | 4.33                       | 82.33             | 5.00                         | 5.00                         | 26.67                      | 3.00                        | 31.33                   | 47.67                    | 1275.67                   | 420.97              | 87.67                      | 3.33                 |
| 10     | VRT-1        | 4.33                       | 101.00            | 5.00                         | 3.33                         | 20.00                      | 3.33                        | 29.67                   | 51.67                    | 1033.00                   | 340.89              | 115.00                     | 3.57                 |
| 11     | VRT-13       | 3.67                       | 89.67             | 5.00                         | 5.33                         | 27.67                      | 4.00                        | 35.67                   | 50.00                    | 1354.67                   | 458.13              | 118.00                     | 4.10                 |
| 12     | Kashi Anupam | 5.33                       | 90.67             | 3.67                         | 7.67                         | 31.00                      | 6.33                        | 42.00                   | 43.67                    | 1353.67                   | 446.71              | 86.67                      | 3.37                 |
| 13     | VRT-2 (p.c)  | 4.33                       | 65.67             | 4.00                         | 4.00                         | 19.33                      | 3.33                        | 31.00                   | 28.67                    | 552.67                    | 182.38              | 45.67                      | 2.67                 |
| 14     | VRT-34       | 4.33                       | 84.00             | 5.00                         | 5.00                         | 24.67                      | 2.33                        | 42.33                   | 42.67                    | 1052.67                   | 347.38              | 86.00                      | 2.73                 |
| 15     | Kashi Amarit | 4.67                       | 78.33             | 4.50                         | 8.67                         | 40.67                      | 3.33                        | 43.33                   | 40.33                    | 1640.00                   | 541.20              | 88.33                      | 3.70                 |
| 16     | VRT-16-1     | 5.00                       | 75.67             | 5.00                         | 5.33                         | 26.00                      | 3.00                        | 26.67                   | 40.33                    | 1046.33                   | 345.29              | 51.67                      | 3.57                 |
| 17     | ToLCV-28     | 4.00                       | 88.33             | 5.00                         | 8.67                         | 45.00                      | 4.67                        | 43.33                   | 41.00                    | 1843.33                   | 608.30              | 93.67                      | 3.17                 |
| 18     | ToLCV-41     | 4.67                       | 92.33             | 4.00                         | 8.00                         | 32.67                      | 5.33                        | 35.00                   | 32.67                    | 1067.67                   | 352.33              | 59.33                      | 2.43                 |
| 19     | H-24         | 4.67                       | 82.33             | 4.33                         | 7.33                         | 29.00                      | 5.67                        | 47.33                   | 48.67                    | 1410.67                   | 465.52              | 123.33                     | 2.83                 |
| 20     | ToLCV-16     | 2.67                       | 82.00             | 2.67                         | 11.67                        | 22.00                      | 5.00                        | 36.67                   | 35.00                    | 746.00                    | 246.18              | 71.67                      | 2.67                 |
|        | Mean         | 4.50                       | 82.58             | 4.34                         | 6.82                         | 29.93                      | 4.10                        | 35.87                   | 40.25                    | 1152.27                   | 380.81              | 78.50                      | 3.00                 |
|        | Man.         | 2.67                       | 60.00             | 2.67                         | 3.33                         | 19.00                      | 2.33                        | 26.67                   | 20.00                    | 552.67                    | 182.38              | 45.33                      | 2.27                 |
|        | Mix.         | 6.00                       | 101.00            | 6.00                         | 11.67                        | 67.67                      | 7.00                        | 47.33                   | 53.33                    | 1843.33                   | 608.30              | 123.33                     | 4.10                 |
|        | SE(d)        | 0.43                       | 2.88              | 0.47                         | 0.56                         | 1.56                       | 0.48                        | 1.44                    | 1.88                     | 59.92                     | 27.26               | 3.43                       | 0.15                 |
|        | C.D. at 5%   | 0.87                       | 5.85              | 0.96                         | 1.15                         | 3.17                       | 0.97                        | 2.93                    | 3.82                     | 121.77                    | 55.40               | 6.97                       | 0.30                 |
|        | C.V. (%)     | 11.70                      | 4.27              | 13.31                        | 10.13                        | 6.38                       | 14.30                       | 4.92                    | 5.73                     | 6.37                      | 8.77                | 5.35                       | 5.94                 |

**Table-4.3. Estimates of genetic variability parameters for 12 characters in Tomato**

| Genotypes                        | Mean    | Mean   |         | Heritability (%) | GA     | Genetic Advance as % mean | GCV (%) | PCV (%) |
|----------------------------------|---------|--------|---------|------------------|--------|---------------------------|---------|---------|
|                                  |         | Min.   | Max.    |                  |        |                           |         |         |
| Number of primary branches       | 4.50    | 2.67   | 6.00    | 68.12            | 1.31   | 29.07                     | 17.10   | 20.71   |
| Plant height (cm)                | 82.58   | 60.00  | 101.00  | 91.91            | 23.45  | 28.39                     | 14.38   | 15.00   |
| lphaNumber of fruits per cluster | 4.34    | 2.67   | 6.00    | 60.97            | 1.16   | 26.76                     | 16.64   | 21.30   |
| Number of clusters per plant     | 6.82    | 3.33   | 11.67   | 92.15            | 4.68   | 68.65                     | 34.72   | 36.17   |
| Number of fruits per plant       | 29.93   | 19.00  | 67.67   | 97.19            | 22.84  | 76.30                     | 37.57   | 38.11   |
| Number of locules per fruit      | 4.10    | 2.33   | 7.00    | 81.47            | 2.29   | 55.77                     | 29.99   | 33.23   |
| Harvest duration (days)          | 35.87   | 26.67  | 47.33   | 91.25            | 11.21  | 31.25                     | 15.88   | 16.62   |
| Average fruit weight (g)         | 40.25   | 20.00  | 53.33   | 93.42            | 17.29  | 42.96                     | 21.58   | 22.32   |
| Fruit yield per plant (g)        | 1152.27 | 552.67 | 1843.33 | 94.11            | 585.94 | 50.85                     | 25.45   | 26.23   |
| Fruit yield /ha (g)              | 380.81  | 182.38 | 608.30  | 89.26            | 187.38 | 49.21                     | 25.28   | 26.76   |
| Number of seeds /fruits          | 78.50   | 45.33  | 123.33  | 97.15            | 49.82  | 63.46                     | 31.25   | 31.71   |
| 1000 seed weight (g)             | 3.00    | 2.27   | 4.10    | 89.02            | 0.99   | 32.87                     | 16.91   | 17.93   |

## CONCLUSION

It is concluded that PCV and GCV were high for number of fruits per plant, number of clusters per plant, number of locules per fruit, number of seeds per fruit, fruit yield per hectare and fruit yield per plant which indicated that high degree of variability in this character and suggests that simple selection could be effective for yield improvement through this trait.

High heritability in broad sense and high genetic advance as percent mean are largely governed by additive gene action and hence there is further scope for effective improvement through selection.

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## GENETIC DIVERSITY IN BRINJAL AND ITS UTILIZATION IN CROP IMPROVEMENT

Taru Dumi<sup>1</sup>, Subhamoy Silkder<sup>2</sup> and Vipin Kumar<sup>3</sup>

<sup>1,2</sup> Uttar Banga Krishi Vishwavidyalaya, Pundibari, Cooch behar, West Bengal

<sup>3</sup> Dept. Of Horticulture, SVPUA&T, Meerut

\*Corresponding Author E-mail– [ummitaru@gmail.com](mailto:ummitaru@gmail.com)

### ABSTRACT

Brinjal is botanically known as *Solanum melongena* and is commonly known by different names like, aubergine, baingan, etc. It is grown widely throughout tropical and temperate regions of the world. Brinjal production varies according to the country and continent. Limited genetic diversity also limits the potential of crop breeding efforts, especially in the face of environmental change. Crop improvement has always relied on genetic diversity; it is due to selection done by the farmers over the years, that most of the biodiversity has been conserved. In any diversity study, the key is the presence of diversity in that particular species whether in the form of crop wild relative or collection of germplasms. There was a need to characterize the brinjal populations collected so that they could then be used as lines for the development of new varieties. Evaluation of genetic diversity is important to identify the source of genes for a particular trait within the available germplasm.

**Keywords:** Brinjal, Genetic diversity, variations.

### INTRODUCTION

Brinjal is botanically known as *Solanum melongena* and is commonly known by different names like, aubergine, baingan, etc. It is grown widely throughout tropical and temperate regions of the world. Brinjal production varies according to the country and continent. China and India are the major producers in the world. *Solanum* is one of the ten most species-rich genera of flowering plants (15) and has approximately 1400 species that occur on all continents except for Antarctica in its wide variety of habitats from deserts to mountain slopes. The genus can be divided into 13 major clades, the largest of which comprises the spiny *solanums*, the *Leptostemonum* clade (subgenus *Leptostemonum* Bitter), with 450 species

distributed all over the world.

Identification of domestication origins are used to identify areas for collection of high genetic diversity for crop improvement Vavilov 1926, and *Solanum melongena* was identified as typical of the “Indo-Chinese centre of origin” by (54). Recent studies suggest a minimum of two separate domestication events, (36) in what is now India and China. It is believed that the brinjal’s ancestor was the subtropical species *S. incanum*, which is a native of North Africa and West Asia (33) and (27) suggested that this wild species is used in brinjal crop improvement programs as a source of variation for phenolics content and resistance to drought. There are some other researchers (59) and (36) who have argued that that the ancestor was rather *S. undatum*. In so much

documentation of Sanskrit, it was found that the domestication of brinjal was achieved around 100–300 BCE. Based on the analysis of microfossils starch grains, suggest that brinjal existed in the diet of people of the Indus valley during the Harappan civilization, thus Rajasthan may have been an area of domestication (24).

Brinjal is an important source of antioxidants, vitamins, and minerals (17). The most important nutritional components of brinjal are phenolic compounds that give the fruit its antioxidant properties (44) which are beneficial for numerous metabolic and cardiovascular diseases. Breeding objectives for brinjal are mostly concerned towards developing high-yielding, early maturing, and high fruit-quality varieties, along with stress resistance and high antioxidants (9; 18). Breeders have performed research with wild relatives of brinjal for yield increase, fruit quality, disease resistance, and more recently, improved nutritional content.

Domestication and succeeding improvement have generally led to the contraction of the genetic diversity of commonly cultivated crop varieties (51). Limited genetic diversity also limits the potential of crop breeding efforts, especially in the face of environmental change. This situation has strengthened research into the use of crop wild relatives, the wild relatives of domesticated crop species, in breeding efforts (21 and 12). Crop wild relatives share a relatively recent common ancestry with present-day species and, due to that close relationship, are reservoirs of genetic traits that can be useful in crop improvement (18). Improvements in yield, fruit and postharvest quality (17 and 16), resistance to plant pathogens (43 and 5), and introduction of abiotic stress traits such as tolerance to increased drought, temperatures, and extreme precipitation are all important, especially in the face of climate change model

predictions of higher temperatures and extreme weather patterns worldwide (6).

Crop wild relatives are an increasingly important source for traits and genes for brinjal improvement (10, 38, 21 and 25), and knowledge about their distribution, traits, and threat status has been the focus of recent studies (50). Crop improvement has always relied on genetic diversity; it is due to selection done by the farmers over the years, that most of the biodiversity has been conserved (49). The local populations usually are genotypes of outstanding inherent value; their ability to adapt to their original environment could make them more suited to sustainable horticulture than hybrids and varieties created in different soil and climate conditions, and which often require higher energy inputs (7).

A characterization of traits is the first step in the description and classification of local genetic resources (48). There was a need to characterize the brinjal populations collected so that they could then be used as lines for the development of new varieties. Evaluation of genetic diversity is important to identify the source of genes for a particular trait within the available germplasm (46 and 23). Unfortunately, the variation present in the wild and cultivated germplasms of brinjal is not adequately characterized. To date, there has been no detailed investigation of variations in the fruit traits of brinjal populations due to a very large amount of variation.

## **EGG PLANT AND ITS SOURCE OF VARIATION**

In any diversity study, the key is the presence of diversity in that particular species whether in the form of crop wild relative or collection of germplasms. Brinjal has many wild relatives which are of which possesses some characters which are superior for the consumers. Incorporation of this wild species

in any crop improvement would be very useful. Some of the wild relatives of *Solanum* are *aethiopicum*, *gilo*, *incanum*, *macrocarpon*, *nigrum*, *torvum*, *pubescens*, *sysimbrifolium*, etc. Eggplant and its wild relatives represent an enormous source of genetic variation for the development of novel varieties to address the challenges posed by biotic and abiotic stresses (58, 39 and 30). They grow in the wild under different environmental conditions such as very hot deserts, very cold temperate areas even in waterlogged and swampy areas with varying degrees of temperatures and thus become resistant to most biotic and abiotic conditions (28, 34 and 11). These advantages of wild eggplant species growing under varying environmental conditions as compared with their cultivated species may play a critical role in the breeding of eggplant varieties that could withstand climate change (13). Furthermore, these wild relatives have been reported to contain high levels of antioxidants especially phenols (26).

Based on biosystematics and crossing data, *S. melongena*, together with nine wild species, form the “eggplant complex”, which includes the cultivated brinjal eggplant and its closest wild relatives (28). The gene pool concept of eggplant was used to categorize wild relatives based on their cross ability with cultivated eggplant into primary, secondary, and tertiary gene pools (20). The primary gene pool of brinjal comprises its wild ancestor *S. insanum* and cultivated eggplant that can be crossed without difficulty to produce fertile and normal hybrids (35 and 44). The secondary gene pool includes many of the wild relatives (more than 40) that are phylogenetically close to *S. melongena*. The success of the crosses, fertility and viability of wild eggplants with cultivated types may be reduced. For instance, the interspecific hybridization derived is partly sterile due to reproductive obstacles such as *S.*

*tomentosum* L., *S. linnaeanum* Hepper, and *S. dasyphyllum*, 31. The tertiary gene pool consists of distantly related species (e.g., *S. sisymbriifolium* Lam, *S. elaeagnifolium* Cav., and *S. torvum* Sw.) used in breeding programs for their resistance characters which require specific cross-breeding techniques to succeed, 30. Phylogenetic relationships between *S. insanum*, the wild progenitor for *S. melongena*, and their closest African wild relative *S. incanum* were recently clarified (45 and 28). *S. dasyphyllum* and *S. anguivi* were confirmed as the wild progenitors of *S. macrocarpon* and *S. aethiopicum*, respectively. The three cultivated eggplants had a common and complex domestication event, as well as morphological changes associated with their domestication 16. Similar seed, plant, and fruit traits were impacted in the same directions, although it seems that the domestication process is more advanced for *S. melongena* than the other two cultivated eggplants 16. At the whole genome scale, the impact of domestication on tomato, pepper, and *S. melongena* has been shown to affect both gene expression and genetic architecture 16. Hence, comparing the domestication signatures on *S. macrocarpon*, *S. aethiopicum*, and *S. melongena* genomes should bring further insights into the similarities and differences between the three cultivated eggplants. *S. macrocarpon* is widely cultivated in tropical America and Asia, while *S. aethiopicum* is popularly grown in South America. The *S. aethiopicum* is a leafy and fruity vegetable that can be cooked or consumed raw. Its leaves can be consumed in the same way as spinach (1).

Not only the wild cultivars but there is a different collection of germplasms all over the world which provides the variation which is necessary for any diversity study. In India the responsibility of collection and preservation of brinjal germplasms was given to the National

Bureau of Plant Genetic Resources, New Delhi by The International Plant Genetic Resources Institute, Rome, Italy. India is one of the primary centres of origin has a rich biodiversity in North Eastern Region, Central Region, and Eastern Ghat. The largest cluster of *S. melongena* was recorded in India, with over 5000 of the total record of 21,000 globally.

Other predominant clusters are in Spain, Southeast Asia, and Turkey, while the major global occurrence of *S. macrocarpon* and *S. aethiopicum* was in West Africa with a total of 1365 and 4230, respectively (41). The Global Gateway to Genetic Resources had a total of 95 accessions of *S. macrocarpon*, 590 of *S. aethiopicum*, and 4056 of *S. melongena*, as reported by (16). The Asian Vegetable Research and Development Centre (AVRDC) Shanhua, Taiwan, is also one of the largest gene bank holders of the three cultivated eggplants with 42 accessions of *S. macrocarpon*, 60 of *S. aethiopicum*, and 2256 of *S. melongena*, as reported by (1), followed by the Plant Genetic Resources Conservation Unit at the University of Georgia. The USDA-ARS had over 800 accessions, including 4 of *S. macrocarpon*, 60 of *S. aethiopicum*, and 770 accessions of *S. melongena* under the Germplasm Resources Information Network (GRIN) database. An estimated 1800 eggplant landraces, cultivars, and wild species in India collected by the National Bureau of Plant Genetic Resources, NBPGR, New Delhi. Similarly, (35) reported close to 2000 eggplant genotypes in China by the Institute of Vegetable Crops, IVC, Nanjing and Hangshu. But the extensive human selection, mutation, domestication, hybridization, and natural inter-crossing have brought about genetic diversity among cultivated eggplants globally. Cultivar differences are mainly concerned with the agronomic and fruit qualities such as shape, color, fruit length, earliness, yield, chemical composition, and environmental requirements.

Determining the presence of genetic diversity in a population.

To determine whether the population is diverse or not we need to find the variation, heritability coupled with genetic advance, an association between the characters, and divergence. For finding the diversity of a particular population, the first and the foremost step is to know the genetic variability available for germplasm which is considered as the reservoir of variability for different characters (49) and it is expressed in terms of phenotypic and genotypic coefficients of variation which are useful in detecting the amount of variability present in the collection of germplasm. The higher difference between GCV and PCV, the higher will be the environmental impact on the studied trait. If the phenotypic coefficient of variation is slightly higher than the genotypic one for all traits, which pointed out the lesser effect of environment on the phenotypic expression of characters. Hence, these characters could be improved by further phenotypic selection. The expression of traits if depends on the environment are not reliable descriptors for morphological characterization (50).

Estimation of heritability is classified as low (<50%), moderate (50-70%), and high (>70%). On the other hand, Genetic advance is classified as low (<20%), moderate (20-50%), and high (>50%). Heritability coupled with genetic advances helps in determining the effect of environment in expression of characters and the range to which the improvement is possible after selection. Heritable and variation, both can be effectively studied in combination with genetic advance. High heritability alone is not enough to make the efficient selection in segregating generation and needs to be accompanied by a substantial amount of genetic advance. High heritability is the indicator of rewarding selection to achieve the desired yield for brinjal germplasms as these characters have

less influence on the environment. Genetic advance is the enhancement over base population which can be gained through selection. High heritability would not be always associated with high genetic advance. Aiming at this, correlation of high heritability combining with genetic advance. They described the effect of genetic advance, which was attributed to genetic variability, amount of environmental masking effect on genetic expression, and intensity of selection. They also recommended that genetic advance would be the key factor for predicting the effects of selection. High heritability with high genetic advance is the result of additive gene action.

Indirect selection is another effective way to study and correlation among different traits of the collection of germplasms hence, essential for an effective selection program because selection for one or more traits results in correlated response for several other traits, and sequence of variation will also be influenced. Thus, the knowledge of the genotypic and phenotypic correlation between yield and its contributing characters is very essential. Correlation studies measure the only mutual association between two traits and it does not imply the cause and effect of the relationship. The existing relationships between traits are generally determined by the genotypic and phenotypic correlations and based on their performance superior traits are selected for further advancement. Alternatively, phenotypic correlation measures the degree of association of two variables and is determined by genetic and environmental factors. Path coefficient analysis is employed to measure the direct and indirect effect of variables on yield. Yield is dependent not only on the interrelationship of associated traits but also on changes in any character that could affect the whole cause-and-effect relationship. Path analysis is a standardized partial regression analysis, which further helps in the partitioning of

correlation coefficient into components of direct and indirect effects of an independent variable on the dependent variable.

Genetic diversity is the information on genetic divergence among the available germplasm is also vital to a plant breeder as it was also observed that the more diverse the parents, the greater are the chances of obtaining high heterotic  $F_1$ s and the broad spectrum of variability in the segregating generation. It is a very potent technique for measuring genetic divergence. The aim of forming clusters and finding the intra and inter-cluster divergence is to provide the base of selecting parents for a planned breeding program. Genetic diversity plays a very important role as it helps in selecting suitable parents for hybridization programs resulting in superior hybrids and desirable recombinants. The clustering pattern of the genotypes was independent of their geographical distribution. Genetic drift and selection in the different environments could cause greater diversity than geographical distance. Based on inter-cluster distances, the genotypes belonging to more divergent clusters should be inter-crossed to generate more variability and improving fruit yield. Genetic diversity can be worked out with the help of  $D^2$  analysis.

## ACHIEVEMENTS

High PCV and GCV for fruit yield per plant, number of fruits per cluster, seeds per fruit, individual fruit weight, leaf area, number of fruits per plant, fruit length, number of flowers per cluster and plant height while, low PCV and GCV for days to 50% flowering and days to first harvest on fifty diverse genotypes (3 and 4). High heritability coupled with high genetic advance was also recorded for number of flowers per cluster, plant height, leaf area, number of fruits per cluster, number of fruits per plant, individual fruit weight, fruit length, fruit diameter, seeds

per fruit and 100 seed weight. (8) studied genetic diversity among 56 eggplant genotypes from three secondary centres of diversity (Bangladesh, Malaysia and Thailand), and observed significant variation for all the morphological traits, and highly significant differences among the three centres of diversity. High heritability and genetic advance were found for different traits i.e., fruit length, fruit diameter, average fruit weight, fruit length to width ratio, number of fruits per plant, fruit yield per plant, plant height and number of primary branches per plant. (42) reported significantly higher amount of variability among the genotypes for all the characters studied viz., days to 50 per cent flowering, number of branches per plant, plant height, number of fruits per plant, days to first picking, Average fruit weight, fruit yield per plot, fruit length, Internodal length, fruit girth and fruit span. The PCV was found to be slightly higher than GCV with medium heritability and genetic advance for 20 diverse genotypes of eggplant under study. (56) studied on twenty varieties of brinjal and when analysis of variance was done it was found that twenty diverse varieties of brinjal differed significantly for the thirteen traits. The highest estimate of phenotypic (PCV) and genotypic (GCV) coefficient of variation were recorded in case of Avg. Fruit Weight (gm) followed by Fruit Circumference (cm) and Average Yield/ Plant (kg) while Days to 50% Flowering exhibited lowest value. The presences of high heritability with high genetic advance in per cent of mean were observed for Average Fruit Weight (gm), Average Yield/ Plant (kg), No. of Primary Branches/ Plant, Fruit Circumference (cm) and No. of Fruits/Plant. (47) experimented on 35 genotypes of brinjal and revealed significant differences among all studied traits. Highly significant differences were observed among all the genotypes and characters under study indicating the presence of sufficient amount of variability in

all the characters. PCV estimates were higher than their corresponding GCV for all characters studied. The heritability estimates were high for all the characters. Expected genetic advance was observed to be high for no. of fruits per cluster, fruit length, fruits weight, no. of fruits per plant, fruit yield per plant, shoot and fruit borer, whereas ascorbic acid content, moderate for fruit width and no. of flower cluster per plant. An investigation was carried out to study genetic parameters for fifteen yield and its contributing characters in 64 (48 F<sub>1</sub>s, 12 lines and 4 testers) genotypes with two check varieties and observed differences among treatments were highly significant for majority of the characters studied in both the years. The pooled analysis of variance also divided the source of variance into environments found highly significant for all the traits under study except for specific gravity. In the year Y<sub>1</sub>, high estimate of heritability in narrow-sense was recorded for fruit length and fruit circumference. In the year Y<sub>2</sub>, high estimate of heritability in narrow-sense was recorded for fruit length followed by fruit circumference, leaf width and dry matter content. In case of over pooled, high estimate of heritability in narrow-sense was recorded for fruit length and fruit circumference. In Y<sub>1</sub>, high estimate of genetic advance in per cent of mean was observed for average fruit weight. In Y<sub>2</sub>, high estimate of genetic advance in per cent of mean was observed for average fruit weight. In over pooled high estimate of genetic advance in per cent of mean was observed for average fruit weight, (31 and 2) studied on thirty-five genotypes and five check varieties and in the analysis of variance it was revealed that mean sum of square due to genotype was highly significant for all fourteen characters studied. High phenotypic and genotypic coefficients of variation, high heritability coupled with high genetic advance as per cent of mean were observed for fruit borer infestation, fruit length, fruit weight, number of fruits per

plant, number of branches per plant, plant height and total fruit yield per plant. (22); studied on 50 local brinjal genotypes (land races) along with two checks of brinjal varieties and found that considerable variability among the genotypes for all the eighteen characters. High phenotypic and genotypic coefficients of variation was recorded for fruit girth. High level of heritability with moderate genetic advance as percentage mean was recorded by protein content.

Path coefficient analysis revealed that average fruit weight, expressed highest positive direct effect on fruit yield per plant followed by yield per hectare, days to maturity, number of fruits per plant, plant height, days to 50% flowering, fruit stalk length. The association analysis revealed that the fruit yield per plant showed significant positive correlation with number of fruits per plant, yield per hectare at genotypic and phenotypic levels and days to first flowering, average fruit weight at genotypic level only (32). The correlation coefficient analysis revealed that fruit yield per plant exhibited maximum positive association with number of fruits per plant followed by marketable yield per plant, number of branches per plant, fruit diameter, fruit weight, days to first flowering. Path coefficient analysis shown maximum positive direct effect on fruit yield per plant through days to first fruit harvest, followed by number of fruits per plant, fruit weight, days to last fruit harvest, days to first flowering and number of branches per plant (40 and 20). The genotypic correlation coefficient was higher in magnitude than the corresponding phenotypic correlation coefficient for most of the characters. The fruit yield per plant had exhibited a highly significant and positive correlation with fruit length and the number of fruits per plant. Path coefficient analysis revealed that the characters viz., the number of fruits per plant, days to first harvest and

fruit girth had a high positive direct effect on fruit yield per plant (47 and 57); Genotypic correlation coefficient was similar in nature and higher in magnitude than the corresponding phenotypic correlation coefficient for most of the characters. Total yield per plant exhibited highly significant and positive relationship with length of the fruit and the number of fruits per plant is significantly but negatively correlated with shoot borer infestation. Thus, the yield per plant can be enhanced by making selection of these traits during the yield improvement programme. The study on path analysis revealed that maximum positive direct effect on yield is exerted by fresh weight of fruit and number of fruits per plant and correlation study revealed that at genotypic level, fresh weight of fruit, fruit volume, number of branches and plant height exhibited significant positive correlation with yield per plant. Maximum significant negative correlation with yield per plant was revealed in anthocyanin content (29).

(52) studied on 24 genotypes and found that fruit width, fruit length and fruit length/width ratio were the main contributors to genetic divergence. (14 and 19) studied on thirty indigenous genotypes and observed the three characters viz., fruit diameter, fruits per cluster and flowers per cluster were the major traits contributing towards genetic divergence. A study was on 32 accessions and it was observed that Individual fruit weight contributed maximum towards diversity followed by number fruits per plant, fruit yield per plant, seeds per fruit, leaf area, fruit length. (4). (24) and (14) studied on 110 locally developed genotypes from different breeding programmes in brinjal and found that out of twelve morphological traits, diversity was brought by average fruit weight, number of fruits per plant, fruit yield per plant and fruit breadth. (55) studied on 40 genotypes and observed that the maximum contribution in

manifestation of total genetic divergence was made by total fruit yield per plant followed by marketable fruit yield per plant. The minimum contribution was noticed in case of number of primary branches per plant and days to first harvesting towards genetic divergence. A study was conducted on thirty-eight genotypes including local landraces and public as well as private sector genotypes of brinjal the maximum contribution towards divergence was made by fruit girth, fruit length, plant height, days to first flowering, days to 50% flowing, node at which first flowering appeared, fruit weight and number of fruits per plant (37).

## CONCLUSION

From the study we can conclude that the study of diversity is a very important pre breeding programme which is done to identify the best genotype with the best quantitative or qualitative traits which are very crucial for the varieties that are to be developed to sustain in this everchanging environment. Crop wild relatives are very important source of diversity which is very important to bring variation in the present-day cultivars of brinjal.

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## EFFECT OF ORGANIC MANURE AND INORGANIC FERTILIZERS ON GROWTH, YIELD AND YIELD ATTRIBUTE IN CAPSICUM (CAPSICUM ANNUM L.) UNDER DHAMPUR, BIJNOR (U.P.) CONDITIONS.

Vinay Kumar<sup>1</sup>, S. L. Pal<sup>2</sup>, Vipin Kumar<sup>3</sup>, Shoraj Singh<sup>4</sup> and Priyanshu<sup>5</sup>

<sup>1,2,5</sup>Dept. of Horticulture, R.S.M. (PG) College Dhampur (Bijnor),  
M.J.P. Rohilkhand University, Bareilly, 243006, Uttar Pradesh, India.

<sup>3</sup>College of Horticulture, Sardar Vallabhbhai Patel University  
of Agriculture & Technology, Meerut (U.P)

<sup>4</sup>Department of Ag. Botany, R.S.M. (PG) College Dhampur (Bijnor),  
M.J.P. Rohilkhand University, Bareilly, 243006, Uttar Pradesh, India.

\*Corresponding Author E-mail– [pg4996278@gmail.com](mailto:pg4996278@gmail.com)

### ABSTRACT

The present investigation was carried out at Horticulture Research centre (HRC), Ranjeet Singh Memorial (PG) College Dhampur Bijnor during the Rabi season of 2019-20. The experiment was laid out in RBD with Total 12 treatments were undertaken i.e., T1 (Control), T2 (100 % FYM 10t/ha), T3 (100 % FYM 20t/ha), T4 (125 %RDF +20t/ha FYM), T5 (100% RDF +10 t/ha FYM), T6 (125 % RDF +10t/ha FYM), T7 (75% RDF) and T8 (100% RDF +20t/ha FYM), T9 (125 % RDF), T10 (75 % RDF 10 t/ha FYM), T11 (100% RDF) and T12 (75%RDF +20t/ha FYM). The results showed that the growth attributes were very much fluctuated in different treatments. As for as yield characters are concerned, it was found that the treatment T8 (100%RDF +20t/ha FYM) was found superior over all the other treatments studied.

**Keywords:** Capsicum, organic manure, inorganic fertilizers, growth, yield

### INTRODUCTION

Capsicum (*Capsicum annum*, 2n = 24) also called as sweet pepper, it is a main vegetable and spice crop originated in the American tropics and today cultivated all over the world for fresh, dried, and processing products. Around the genus Capsicum there is an increasing interest and fascination due to the considerable variation for several traits, which makes this crop extremely versatile and suitable for innumerable uses as food and non-food products. While each existing pepper variety can be categorized into one of these five species, there are 25 known species in the Capsicum genus, most of them being

non-domesticated and five of which (*C. annum*, *C. frutescens*, *C. chinense*, *C. baccatum*, and *C. pubescens*) are domesticated and mainly grown for consumption. A large number of accessions of domesticated and wild species are stored in the world seed banks, representing a valuable resource for breeding in order to transfer traits related to resistances to various abiotic and biotic stresses as well for quality improvement. It has a bidirectional root system. Plants are bushy, about 60–80cm high and semi-perennials that are grown as annuals in commercial cultivation. Capsicum peppers were introduced to Asia in the sixteenth

century by Portuguese and Spanish explorers via trade routes from South America. It has attained a status of high value crop in India in recent years with the import of improved varieties and is enjoying a pride place among vegetables in Indian cuisine because of its delicacy and pleasant flavour coupled with rich content of ascorbic acid, other vitamins and minerals. Mostly, green colour varieties are grown throughout India under open field conditions and the produce from hilly regions like Himachal Pradesh fetches off season prices to the growers. These crops account for 37% of the total exports of agricultural commodities from India. The total area under cultivation of capsicum 34 ha and production is estimated to be 515 million tons in 2019-20 (NHB).

For realizing higher yields and quality produce, soil health is a critical factor. Therefore, chemical fertilizers must be integrated with organic manures such as, FYM, Poultry manure, Vermicompost, crop residues. Which are renewable and eco-friendly to achieve sustainable productivity with minimum deleterious effects of chemical fertilizers on soil health and environment? Organic manures are the plant and animal waste that are used after decomposition. The decomposed mixture of dung and urine of farm animal along with litter and other materials from roughages or fodder fed to cattle is farmyard manure (FYM). On an average well decomposed farm yard manure contains 0.5% N, 0.3% P<sub>2</sub>O<sub>5</sub> and 0.5% K<sub>2</sub>O. It can supply practically all the elements of soil fertility that the crops require, though not in adequate amounts and in right proportions. The plant food elements contained in manure are released in an available form upon decomposition by soil microorganisms. Combined application of organic and inorganic fertilizers attained a great significance in vegetable production as large amount of nutrients required for

continuous production, hectare-1 yield of vegetables and fertilizer alone cannot sustain the productivity of soils under highly intensive cropping systems. Further, use of organic manures in integrated nutrient management help in mitigating multiple nutrient deficiencies. Soil health is one of the key factors which decide the yield (15). Organic manures are basic source of essential plant nutrients and applied in large quantities. Application of organic manures to soil not only improves the physical properties but also increases the availability of nutrients. It supplies the plant nutrients including micronutrients to increase the yield of crop (11)

## **MATERIALS AND METHODS**

The present research works were carried out at Horticulture Research centre (HRC), Ranjeet Singh Memorial (PG) College Dhampur Bijnor during the Rabi season of 2019-20. Geographically it is situated between 29° 55' latitude in the north and 78° 80' East longitudes in the eastern elevation of about 290 m (948 ft) above mean sea level. The experiments were laid down in a Randomized Block Design with three replications. California wonder is a variety of capsicum was sown at a distance of 60cm Row to Row and 30 cm Plant to Plant as per spacing of sown. Total 12 treatments were undertaken i.e., T1 (Control), T2 (100% FYM 10t/ha), T3 (100% FYM 20t/ha), T4 (125%RDF +20t/ha FYM), T5 (100%RDF +10t/ha FYM), T6 (125%RDF +10 t/ha FYM), T7 (75%RDF) and T8 (100%RDF +20t/ha FYM), T9 (125% RDF), T10 (75%RDF 10t/ha FYM), T11 (100%RDF) and T12 (75%RDF +20t/ha FYM). The observations were recorded during the course of experimentation on following characters- Plant height (cm), Number of leaves per plant, Leaf width (cm), Diameter of stem (mm), Number of branches per plant, Number of fruits per plant, Weight of fruit per plant (g), Fruit yield per plot (kg) and Fruit yield q/ha were recorded during the course of experimentation. Average of data from the sampled plant of each treatment was

used for statistical analyses in order to draw valid conclusions.

## RESULTS AND DISCUSSION

Result shown that treatments have wide range of variation in respect of plant height of all treatments, maximum plant height recorded in the treatment T8 (6.45cm) which was followed by T3 (5.97cm), T4 (5.90cm) and while minimum plant height (4.80cm) was recorded in T1. Result revealed that treatments have wide range of variation in respect of plant height of all treatments, T8 maximum plant height (54.03cm) followed by (53.63cm) in T3 where as T1 had minimum plant height (31.60cm). It is a good source of organic matter which would have improved the physico-chemical properties of soil and there by resulted in better plant height of Capsicum. Similar results were reported by (7), (9) and (3). Number of leaves per plant 30 DAT: Result have shown that treatments have wide range of variation in respect of number of leaves per plant all treatments, the maximum number of leaves per plant recorded in the treatment T8 (6.80) which was found statistically at par with T3 (6.57) and T12 (6.37) while minimum leaves per plant (4.57) was recorded in T1.

### Number of leaves per plant 120 DAT

Result revealed that treatments have wide range of variation in respect of number of leaves per plant T8 maximum leaves per plant (32.37) followed by (31.93) in T3 where as T1 minimum leaves per plant (20.93). Maximum number of leaves might be due to fact that application of NPK and Vermicompost provided adequate Nitrogen which is associated with high photo synthetic activity and vigorous vegetative growth. Similar results were reported by (12), (13) and (15).

### Leaf width 30 DAT

Result revealed that treatments have wide range of variation in respect of leaf width, T8 maximum leaf width (2.63cm) followed by (2.60cm) in T3 where as T1 have minimum leaf

width (2.10cm).

### Leaf width 120 DAT

Result shown that treatments have wide range of variation in respect of leaf width, T8 maximum leaf width (4.77cm) followed by (4.37cm) in T3 where as T1 had minimum leaf width (3.67cm).

### Diameter of stem (mm) 30 DAT:

Result have been shown that wide range of variation in respect diameter of stem, the maximum diameter of stem recorded in the treatment T8 (4.10 mm) which was found statistically followed by T3 (3.77 mm) and T12 (3.57 mm) while minimum diameter of stem (3.00 mm) was recorded in T1.

### Diameter of stem (mm) 120 DAT

Result have been shown that wide range of variation in respect diameter of stem, the maximum diameter of stem recorded in the treatment T8 (27.13mm) which was found statistically followed by T3 (26.80 mm) and T10 (26.93 mm) while minimum diameter of stem (19.70mm) was recorded in T1.

### Number of Branches per plant 30 DAT

Among the maximum Number of branches per plant recorded in the treatment T8 (4.73) which was found statistically followed with T3 (4.50) and T12 (4.47) while minimum branches per plant (3.13) was recorded in T1.

### Number of Branches per plant 120 DAT

Result have been shown that wide range of variation in Number of Branches per plant , the maximum branches per plant recorded in the treatment T8 (26.37) which was found statistically followed with T3 (25.87) and T12 (24.90) while minimum branches per plant (15.97) was recorded in T1.

### Number of fruits per plant 120 DAT

Result revealed has been shown that wide range of variation in respect of T8 maximum number of fruits per plant (6.80) followed by (6.23) in T3 where as T1 have minimum

number of fruits per plant (4.23).

### **Number of fruits per plant 180 DAT**

Result revealed that treatments have wide range of variation in respect T8 maximum number of fruits per plant (17.57) followed by (17.33) in T3 where as T1 have minimum number of fruits per plant (12.67).

### **Weight per fruit (gm) 120 DAT**

Result revealed has been shown that wide range of variation in respect of the maximum weight per fruit recorded in the treatment T8 (65.20gm) which was found statistically followed with T3 (63.67gm) and T12 (63.40 gm), while minimum weight per fruit (49.93gm) was recorded in T1.

### **Weight per fruit (gm) 160 DAT**

Result revealed has been shown that wide range of variation in respect of the maximum weight per fruit recorded in the treatment T8 (69.17gm) which was found statistically at followed with T3 (67.93gm) and T12 (67.57gm) while minimum weight per fruit (51.13gm) was recorded in T1.

### **Fruit yield per plot (kg)**

Result revealed that treatments have wide range of variation in respect of T8 maximum number of fruits per plant 9.8kg followed by 9.01kg in T3 where as T1 had minimum number of fruits per plant 7.18kg.

### **Fruit yield (q/ha)**

Result revealed that treatments have wide range of variation in respect of T8 maximum of fruits yield 273q/ha followed by 250.30q/ha in T3 where as T1 have minimum fruits 199.55q/ha. Similar results were obtained by (7), (8) and (3)

Plant height (cm), number of leaves per plant, stem diameter (mm) and leaf width

were influenced significantly at all stage of growth due to variety and nutrient levels and Treatment has wide range of variation in respect of all the characters. Treatment T8 (100%RDF+20tanFYM) was found superior for all the vegetative growth characters. However, this treatment was statistically at par with T3 (100% FYM 10tan) in case of all the characters studied. Therefore, potassium fertilization improved overall growth in term of plant height, number of leaves of per plant with application of FYM and NPK might be better moisture holding capacity and availability of major and micro nutrients due to favourable soil conditions. Result of (10) in capsicum, (5) in capsicum, (8) in capsicum.

Most of the yield and yield attributing characters like days to first picking, days to last picking, number of fruit per plant, weight of weight per fruit 160 and 180day, fruit yield per plot, fruit q/h was very much influenced by adequate use of integrated nutrient management like FYM, nitrogen phosphorus potash+ farm yard manure .Treatment T8 (100% RDF+20tan FYM) was observed superior for all the yield attributes parameters. However, this treatment was statistically at par with T3 (100%FYM 20tan) in case of all the characters studied. Improve overall growth with nitrogen fertilizer coupled with increased net photosynthesis on one hand and greater mobilization of photosynthesis towards depository stature, on the other hand might have increased the yield significantly. Increased levels of FYM along with combination of chemical fertilizer was found significant for number of green pods per plant, weight of individual green fruit , green fruit yield per plant, green fruit yield per plot, green fruit yield /ha. The results are in accordance with (6) in capsicum, (8) in capsicum, (2) in capsicum.

**Table 1: Mean performance of Capsicum (*Capsicum annum* L.) cv. California wonder by organic manure and inorganic fertilizer treatments-**

| Treatment       | Combination          | Plant height (cm) |         | No. of leaves per plant |         | Leaf width |         | Diameter of stem (mm) |          | No. of branches per plant |         | No. of fruit per plant |         | Weight of fruit (gm) |         | Fruit yield per plot (kg) | Fruit yield q/ha |
|-----------------|----------------------|-------------------|---------|-------------------------|---------|------------|---------|-----------------------|----------|---------------------------|---------|------------------------|---------|----------------------|---------|---------------------------|------------------|
|                 |                      | 30 DAT            | 120 DAT | 30 DAT                  | 120 DAT | 30 DAT     | 120 DAT | 30 DAT                | 120 DAT  | 30 DAT                    | 120 DAT | 120 DAT                | 180 DAT | 120 DAT              | 160 DAT |                           |                  |
| T <sub>1</sub>  | Control              | 4.8               | 31.6    | 4.57                    | 20.93   | 2.10       | 3.67    | 3.00                  | 19.70    | 3.13                      | 15.97   | 4.23                   | 12.67   | 49.83                | 51.13   | 7.18                      | 199.55           |
| T <sub>2</sub>  | 100% fym 10t/ha      | 5.23              | 52.77   | 6.33                    | 28.5    | 2.47       | 4.53    | 3.40                  | 25.97    | 3.93                      | 21.77   | 5.93                   | 16.57   | 55.37                | 64.80   | 7.42                      | 206.03           |
| T <sub>3</sub>  | 100% fym 20t/ha      | 5.97              | 53.63   | 6.57                    | 31.93   | 2.60       | 4.37    | 3.77                  | 26.80    | 4.50                      | 25.87   | 6.23                   | 17.33   | 63.67                | 67.93   | 9.01                      | 250.30           |
| T <sub>4</sub>  | 125%RDF + 20t/ha FYM | 5.9               | 51.57   | 6.07                    | 31.07   | 2.43       | 4.13    | 3.23                  | 25.73    | 4.33                      | 24.47   | 5.57                   | 16.73   | 61.60                | 65.80   | 7.87                      | 218.53           |
| T <sub>5</sub>  | 100%RDF +10t/ha FYM  | 5.07              | 53.70   | 5.7                     | 31.73   | 2.53       | 4.30    | 3.17                  | 26.57    | 4.17                      | 23.87   | 5.87                   | 16.53   | 62.93                | 66.50   | 7.99                      | 222.05           |
| T <sub>6</sub>  | 125%RDF +10t/ha FYM  | 5.15              | 53.37   | 6.23                    | 31.87   | 2.40       | 4.10    | 3.27                  | 26.37    | 4.40                      | 24.27   | 6.10                   | 17.20   | 57.27                | 66.73   | 7.47                      | 207.42           |
| T <sub>7</sub>  | 75%RDF               | 5.71              | 51.37   | 6                       | 31.23   | 2.53       | 4.33    | 3.37                  | 26.17    | 4.33                      | 24.10   | 6.03                   | 17.03   | 53.67                | 66.30   | 8.00                      | 222.33           |
| T <sub>8</sub>  | 100%RDF +20t/ha FYM  | 6.45              | 54.03   | 6.8                     | 32.37   | 2.63       | 4.77    | 4.10                  | 26.13    | 4.73                      | 26.37   | 6.80                   | 17.57   | 65.20                | 69.17   | 9.84                      | 273.45           |
| T <sub>9</sub>  | 125%RDF              | 5.51              | 49.23   | 6.13                    | 29.87   | 2.40       | 4.20    | 3.33                  | 27.13    | 4.50                      | 22.70   | 6.00                   | 16.73   | 57.23                | 65.17   | 8.17                      | 226.87           |
| T <sub>10</sub> | 75%RDF 10t/ha FYM    | 5.07              | 51.6    | 6.13                    | 30.77   | 2.23       | 4.33    | 3.43                  | 26.07    | 4.30                      | 23.87   | 5.97                   | 16.80   | 60.13                | 66.73   | 8.08                      | 224.56           |
| T <sub>11</sub> | 100%RDF              | 5.5               | 52.03   | 6.13                    | 31.87   | 2.53       | 4.20    | 3.40                  | 26.93    | 4.23                      | 24.20   | 5.33                   | 17.10   | 57.00                | 65.43   | 8.10                      | 225.02           |
| T <sub>12</sub> | 75%RDF +20t/ha FYM   | 5.83              | 53.5    | 6.37                    | 31.43   | 2.57       | 4.33    | 3.57                  | 26.40    | 4.47                      | 24.90   | 6.20                   | 17.27   | 63.40                | 67.57   | 8.18                      | 227.15           |
|                 | Mean                 | 5.52              | 50.7    | 6.09                    | 30.3    | 2.5        | 4.27    | 3.42                  | 26.73    | 4.25                      | 23.53   | 5.86                   | 16.63   | 58.94                | 65.27   | 8.11                      | 225.27           |
|                 | Minimum              | 4.8               | 31.6    | 4.57                    | 20.93   | 2.10       | 3.67    | 3.00                  | 25.88    | 3.13                      | 15.97   | 4.23                   | 12.67   | 49.83                | 51.13   | 7.18                      | 199.55           |
|                 | S.Em. ±              | 0.39              | 1.33    | 0.33                    | 0.71    | 0.09       | 0.17    | 0.16                  | 19.70    | 0.18                      | 0.77    | 0.28                   | 0.39    | 2.24                 | 0.84    | 0.19                      | 5.28             |
|                 | CD at 5%             | NS                | 3.92    | 0.98                    | 2.09    | 0.26       | 0.51    | 0.47                  | 0.61     | 0.54                      | 2.28    | 0.81                   | 1.15    | 6.62                 | 2.49    | 0.56                      | 15.58            |
|                 | C.V. (%)             | 12.34             | 4.54    | 9.45                    | 4.04    | 6.30       | 6.97    | 8.12                  | 41.81.11 | 7.48                      | 5.69    | 8.15                   | 4.05    | 6.59                 | 2.24    | 4.06                      | 4.06             |

## CONCLUSION

On the basis of results emanated from present investigation that application of 100%RDF +20t/ha FYM proved best in respect of better growth and yield as well as for quality parameters. The treatment 100%RDF +20t/ha FYM were found better than the rest of the treatments for yield and most of the yield attributing characters. This treatment may be considered as guidelines for future enhancement of growth, yield and quality parameters in Capsicum.

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## **NANO-BIOTECHNOLOGY FOR SUSTAINABLE AGRICULTURE : RECENT DEVELOPMENTS, CHALLENGES AND FUTURE PERSPECTIVES**

**Neelesh Kapoor<sup>1\*</sup>, Arzoo<sup>2</sup>, Rekha Dixit<sup>3</sup>, Anil Sirohi<sup>4</sup>,  
Vipin Kumar<sup>5</sup> and Ravindra Kumar<sup>6</sup>**

<sup>1,4</sup>Division of Plant Biotechnology, College of Biotechnology, SVPUA&T, Modipuram, Meerut

<sup>2</sup>Department of Biotechnology, MIET, Meerut

<sup>3</sup>Division of Microbial & Environmental Biotechnology, College of Biotechnology,  
SVPUA&T, Modipuram, Meerut

<sup>5</sup>College of Horticulture, SVPUA&T, Modipuram, Meerut

\*Corresponding Author E-mail– [drneeshbiotech@gmail.com](mailto:drneeshbiotech@gmail.com)

### **ABSTRACT**

Nanotechnology is a budding branch of science that is capable of creating a positive impact on the agriculture sector in various ways such as preventing and reducing the harmful effects of bad agricultural practices on human and environment health, which will eventually assist in improving food security and productivity. Nanomaterials possess such novel physiochemical properties that are perfect for developing helpful tools for sustainable agriculture. Due to their efficient delivery system, nanomaterials are being used to immobilize nutrients so that they can be delivered in soil quickly and effectively; this helps in minimizing leaching while promoting nutrient uptake by plants (1,2). This property can also be utilized to deliver pesticides or fertilizers at targeted locations on desired time via intelligent nano systems. It will help in preventing the flow of chemicals into the environment and also reducing the damage to other plants. Over the years nanomaterials have been used for smart food packaging, for environmental monitoring, for better plant growth and development, and for detecting nutrient deficiencies. Nanoparticle treatments have shown promising results in early seed germination and improved vigour index (7, 21). However, for the worldwide acceptance of nanotechnology-based approaches and nano-enabled food products, we need to make the public aware of it. There should be enough evidence present to justify the safe use of nanomaterials in the food sector and agriculture. Thus, the current review article is focused on various issues related to impact of nano-biotechnology on agriculture.

**Keywords:** Nanotechnology, nanobiotechnology, sustainable agriculture, biosensors

### **INTRODUCTION**

Nanotechnology is the advanced field of research; it offers many opportunities in the present and is expected to evolve in the future in a variety of industries. It has revolutionized areas such as physics, chemistry, material

science, engineering, agriculture, biology and medicine. Nanotechnology refers to materials, systems and processes that operate at a scale of 100 nm or less. A nanometer is one billionth of a meter. Overall nano refers to a size scale ranging from 1 and 100 nm. By Bottom-up/top-down approaches

nanoparticles can be synthesized using a range of materials. The materials used include metal oxides, ceramics, magnetic materials, semiconductor quantum dots, lipids, polymers, dendrimers and emulsions. By uniting the fields of material science and biology, nanomaterials can be used for biotechnology applications. Various nanostructures with highly controlled properties have developed interest in their use in the biotechnology field. For the development of nanomaterials for different biological applications, non-toxic, biocompatible and biodegradable nanomaterials are used. For agriculture applications, metal oxide nanoparticles and carbon-based materials are currently being used to explore the phytotoxicity and environmental toxicity. However, nanoparticles may have positive or negative effects on plants. One of the concerns for nanomaterials applications is their phytotoxicity in seed germination. The phytotoxicity level may depend on the type of nanomaterial. For the development of nanomaterials, strong knowledge of biological processes at nanoscale is required (22).

## NANOTECHNOLOGY IN AGRICULTURE

Agriculture is the most important sector because it produces raw materials for food and feed industries. Excessive use of pesticides and fertilizers leads to environmental pollution; increasing agricultural pests and pathogens; and loss of biodiversity. The limited number of natural resources (non-renewable) and rapidly growing population require effective, economic and environment-friendly agricultural practices. Nanomaterials have agro-biotechnological solutions to these problems (32). Nanotechnology produces, manipulates and deploys nanomaterials that play an important role in agriculture. The

problems related to agrochemicals, fertilizers, pesticides, herbicides regulation, and smart utilization can be overcome by nanoscience which includes new materials and technologies. Due to their physiochemical properties such as small size, high surface-to-volume ratio, and unique optical properties, nanomaterials are used for plant defense and nutrition (18). Agricultural applications of different nanomaterials are portrayed in the schematic diagram (Figure 2.1).

Figure 2.1: Agricultural applications of nanomaterials.

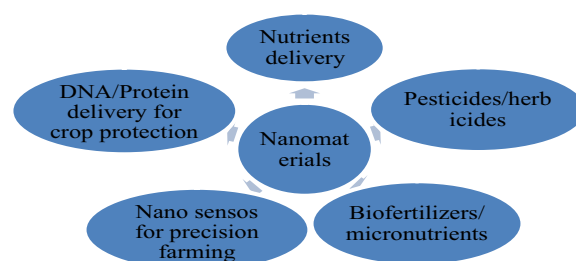


Figure 2.1: Agricultural applications of nanomaterials.

Moreover, the mechanism of some nanoparticles reveals that they can penetrate into the plants that can either enhance or decrease their growth. The following Figure 2.2 depicts the uptake and translocation of nanoparticles in plants (8).

Figure 2.2: Pathways of nanoparticle association, uptake and translocation in plants.

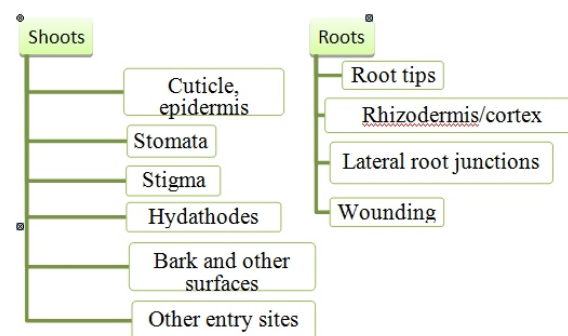


Figure 2.2: Pathways of nanoparticle association, uptake and translocation in plants.

The benefits of nanomaterial-based formulations are the improvement of efficacy,

higher solubility, induction of systemic activity due to smaller particle size, higher mobility and lower toxicity in comparison to conventional pesticides (25). Thus, seeking potential nanomaterials for the benefit of plant growth and yield is increasing in the present scenario. Nanotechnology helps in reducing environmental pollution by production of pesticides and chemical fertilizers using the nanoparticles, developing nano capsules with the ability of controlled delivery to specific sites at desired time, and production of nano-crystals to increase the efficiency of pesticides even with lower dose. They can alter the kinetic profiles of drug release, leading to sustainable release of drugs with reduced requirement for frequent dosing. Nanotechnology can indirectly protect the environment by use of alternative (renewable) energy supplies and nano-filters to reduce pollution (29).

### Applications of Nanotechnology in Agriculture

The various applications of nanotechnology in agriculture are as follows (Table 3.1):

| Application                                                    | Example                                                                                                                    | Reference            |
|----------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|----------------------|
| Carbon nanomaterials (artificial nose)                         | Artificial nose used to detect pathogens depending on the organic compounds released.                                      | Cui et. al., 2018    |
| Nanobiosensors (pesticide detection)                           | Graphene based with molecularly imprinted polymers used for pesticide detection of chlorothalonil and chlorpyrifos methyl. | Xuet. al., 2020      |
| Silver nanoparticles (synthesized using <i>Sonchus asper</i> ) | The use of silver nanoparticles led to high seed germination percentage and better seedling growth in fenugreek plants.    | Kapoor et. al., 2018 |

|                                                               |                                                                                                                                                                               |                            |
|---------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|
| Nanosensors (plant hormone)                                   | Receptor DAD2 from <i>Petunia</i> hybrid and HTLT from <i>Strigahermohthica</i> used for detection of strigolactones as signalling molecules for plant growth and parasitism. | Chesterfield et. al., 2020 |
| Water retention (nanomaterials e.g., zeolites and nano-clays) | Nano-clay for water or agrochemical retention and slow release to the plants.                                                                                                 | Geohumus, 2017             |
| Plant disease diagnosis (Multiwalled carbon nanotubes)        | Detection of Cymbidium Mosaic virus                                                                                                                                           | Antonacciet. al., 2017     |

Table 3.1- Recent applications of Nanotechnology in Agriculture

## NANOBIOSENSORS

Nanobiosensors are devices having at least one dimension less than 100 nm. They can be structured as nanowires, nanoparticles, nanotubes or nanocrystals. They can be designed to monitor plants, soil and water in the field. Nanobiosensors have shown to possess better functionality than the analytical sensors. Nanobiosensors are based on the principle of recognition of biological elements by their specific chemical or physical properties (15). These chemical signals are converted into electrical signals by the transducer and can be detected through the device. This allows the real time detection and control of the crop needs such as early disease detection, water and nutrients supply at the required time (19). These are used for monitoring soil conditions (e.g. moisture, soil pH), a wide variety of pesticides, herbicides, fertilizers, insecticides, pathogens and crop growth as well as for detection of food-borne contaminants or for monitoring environmental conditions at the farm. Aptasensors are used to determine pesticides and insecticides (e.g. acetamiprid,

isocarbophos). Nanobiosensors can also be used for determination of antibiotics, drugs and their residues (e.g. cocaine, oxytetracycline, tetracycline, kanamycin) and for determination of heavy metals (20). Nanobiosensors mainly consist of three components (10):

- i. Biological sensitive probe: Probe interacts with the biomolecule to tell its concentration. Some examples of probe and biomolecule interaction include antibody–antigen interaction, nucleic acid interactions, enzymatic interactions and cellular interactions (i.e., microorganisms, proteins).
- ii. Transducer: This component of the sensor converts signals from biomolecules into electrochemical, optical and mass-sensitive signals.
- iii. Data recording unit: this unit amplifies the signal, analyses the data and stores it. Data is directed to the gateways to transfer the data from Nanobiosensors to the internet (9).

Strategies are being developed to spray the suspension of nano-scale sensing devices on the plant leaves to adequately monitor the plant surface. At this time, this technology is at its very early stage. Nano-networks can help in monitoring plant conditions and suggesting a more efficient usage of crop inputs (e.g., fertilizers, water, pesticide, etc). This will result in improved quality, reduced cost and less wastage of the crop products.

## In Crop Improvement

Mutations have always played a great role in crop improvement. Instead of using conventional methods for induced mutation by chemical and physical mutagens nanotechnology can be used for inducing mutations. Chiang Mai University's Nuclear Physics Laboratory in Thailand has developed a white grain rice variety from a purple colored rice variety called "KhaoKam" by using nanotechnology. Scientists changed the purple stem, leaves and grains into whitish color by using nanotechnology. They drilled a

nano-sized hole through the wall and membrane of a rice cell to insert a nitrogen atom. A particle beam (a stream of fast-moving particles) was used to drill the hole and the nitrogen atom was shot through the hole to stimulate rearrangement of DNA in the rice. The organism so developed was called "Atomically Modified Organisms (AMOs)" (34).

## Silver Nanoparticles

Silver Nanoparticles have grabbed much consideration in agriculture due to their tiny size and novel properties. A number of studies have been carried out on the effect of silver nanoparticles obtained after chemical reduction on the plants. Studies have shown the reduced frequency of root diseases after application of silver nanoparticles solution in the plants. Also, the colloidal nano silver solution can significantly improve plant growth and health (12).

## Nanofabricated Gel-free DNA Sequencing

As a central process, DNA sequencing needs to be improved in terms of its throughput and accuracy. Nanofabrication technology will be critical toward this goal both in terms of improving existing methods as well as delivering novel approaches for sequence detection. The scaling down in size of the current sequencing technology allows the process to be more parallel and multiplex. Research has shown the advancement in nanobiotechnology to sequence DNA in nanofabricated gel-free systems. This will lead to much more efficient and rapid DNA sequencing (4). The sequenced data from the cultivated crops and its wild varieties can prove to be very beneficial in finding the information about molecular markers associated with important crop traits (28).

## MESOPOROUS SILICA NANOPARTICLES

Mesoporous silica Nanoparticles (MSN) possesses finest properties such as high specific area, high pore volume, tunable pore structures and physicochemical stability. It helps in delivering DNA and chemicals into isolated plant cells. MSNs are chemically coated and serve as containers for the genes delivered into the plants. The coating stimulates the plant to receive the particles through the cell walls. It was found that MPS/DNA complexes showed increased efficiency of transfection by mannose receptors-mediated endocytosis. These results show that MPS can be used as a possible gene carrier to antigen presenting cells in the future (31).

### Micro-Chips

Microarray chips allow the measurement of the expression level of genes. This method provides the information about function and regulation of genes and has become a central tool in biological research. DNA and protein molecules are arrayed on glass slides to create DNA and protein chips. These chips can be nanofabricated with the patterns of biosensors for various applications in agriculture (23). DNA microarrays have following applications: Finding DNA sequences, looking for polymorphisms in genes, improved screening of microbes used in bioremediation, and scanning for gene patterns and expressions due to any mutation or stress. Protein microarrays can help in finding protein biomarkers to identify the disease stages and also to differentiate between the protein production in healthy and diseased cells. Simultaneously, we can find protein-protein interactions and relation between protein structures and function (33).

## PLANT DISEASE DIAGNOSTICS

Diseases are one of the major factors that limit crop production. Problem is the

detection of diseases at the later stages. To avoid any diseases, pesticides are applied as a preventive measure but it can lead to toxicity in plants and soil and also cause environmental hazards. Some of the viral diseases cannot be prevented by application of pesticides at later stages, so early detection of the viral disease is necessary. Nano-based kits have been developed for diagnosis of viral diseases at initial stages. Therapeutics can be developed and applied according to the stage of disease (17). Biomarkers have also been developed to find the exact stage of the disease. Nano-based Diagnostic kits are rapid in detection with better results (26).

### Cellulose Nanofibers

Cellulose is abundantly found in plant tissues. It is mainly found in lignocellulosic material in wood which is a great source of cellulose for industries. Cellulose can also be obtained from grasses, agriculture residues, plants and their substances (16). In plants, cellulose fibre structure is made up of micro and macro fibrils. These microfibrils consist of elementary fibrils (nanofibers) that have a diameter of 3–35 nm depending upon the source of cellulose (2). Nanocellulose is emerging as a new bio-based nanomaterial that has great optical properties, high strength and specific surface area (35). Nanocellulose can be extracted and chemically modified for its applications in the field of nanobiotechnology (30). Soy hulls, wheat straw, sugar beet pulp, potato pulp and rutabaga, are already being used as raw materials for cheaper nanocellulose production (24).

### Quantum dots

QDs have distinctive properties compared to conventional organic dyes; therefore recently, they have been applied as a new generation of fluorophores in bioimaging and biosensing (3). It acts as photocatalysts for the light driven chemical conversion of water into

hydrogen as a pathway to solar fuel. QDs at low concentration do not reveal measurable cytotoxicity for seed germination and seedling growth. These can be utilized for live imaging in plant root systems to verify known physiological processes (7).

## NANOPARTICLES

By using a point-of-source purification device, zinc oxide nanoparticles can be used to remove arsenic. Nanoscale zeolites, metal oxides, carbon nanotubes and fibres, enzymes, various noble metals (mainly as bimetallic nanoparticles) and titanium dioxide are other nanomaterials that could be used for remediation. Nanoparticle filters can be used to remove organic particles and pesticides (for example, dichlorobiphenyl-trichloroethane (DDT), endosulfan, malathion and chlor-pyrifos) from water. In developed countries a variety of nanoparticle filters were used in remediation of waste sites (14). It is now possible to use magnetic nanoparticles and magnetic separations at very low magnetic field gradients. Nanocrystals, such as monodisperse magnetite ( $\text{Fe}_3\text{O}_4$ ) have a strong and irreversible interaction with arsenic while retaining their magnetic properties. To remove nanocrystals and arsenic from water a simple handheld magnet can be used. Therefore, such a treatment could be used for filtration of irrigation water (37).

## Nanoencapsulation

Nano-encapsulation with nanoparticles in the form of pesticides allows for proper absorption of the chemicals into the plants. This method can also deliver DNA and other necessary chemicals into plant tissues to protect host plants from insect pests. In its pesticide products, Syngenta, the world's largest agrochemical company uses nano emulsions. One of its successful growths regulating products is the Primo MAXX® plant growth regulator, which, when applied

prior to the onset of stress such as heat, drought, disease or traffic can build up the physical structure of turf grass and enable it to withstand continuous stresses throughout the growing season. Marketed under the name Karate® ZEON this is a rapid release microencapsulated product containing the active compound lambda-cyhalothrin (a synthetic insecticide based on the structure of natural pyrethrins) that breaks open when contact with leaves occurs. In contrast, the encapsulated product "gut buster" only breaks open to release its contents when it comes into contact with alkaline environments, such as the stomach of certain insects (27).

## Zeolites

These are naturally occurring crystalline aluminium silicates. It helps to penetrate and retain water in the soil because of its very porous properties and capillary suction it exerts. It acts as a natural wetting agent and is an excellent amendment for non-wetting sands, facilitating the transfer of water through soils and enhancing the ability of soil to retain nutrients and produce improved yields (21).

## FUTURE PROSPECTS OF NANOTECHNOLOGY IN AGRICULTURE

Nanotechnology is an integration where the structure of matter is controlled at the nanoscale to produce materials with unique properties such as high surface area, targeted site of action and slow release. Nanoparticles, have in the range of 1-100 nm. In the current scenario, the farming community faces a wide range of challenges such as stagnant productivity, crop destruction due to pest attack, loss of soil fertility, inadequate water, fluctuating weather conditions and soil contamination loss. To combat and resolve these difficulties, Nano-agroparticles or nanometric particles are designed. These

Nano-agroparticles efficiently can act as fungicidal, insecticidal agents, herbicides, pesticides and as plant growth promoters. With the help of *in situ* portable nanotechnology-guided detection, monitoring and analysis, farmers would be able to improve their agricultural outcomes. The administration of nanoparticles in safe dosages can facilitate plant growth and crop productivity.

Nanotechnology in precision agriculture can also help recycle agricultural waste and thereby minimize environmental pollution. Although the tiny sensors and monitoring systems enabled by nanotechnology will have a big impact on future precision farming methodologies. A major role for nanotechnology-enabled devices will be the increased use of autonomous sensors connected to a GPS for real-time analysis. These Nanosensors could be deployed throughout the field where they can monitor soil conditions and crop growth. Nanotechnology in precision agriculture can also help recycle agricultural waste and thus keep environmental pollution to a minimum. Although the tiny sensors and monitoring systems enabled by nanotechnology will have a big impact on future precision farming methodologies. These includes:

- **Nanosensors:** They are also being developed to increase soil fertility and agricultural production. Nanosensors can also monitor the health of crops and magnetic nanoparticles can facilitate the removal of soil contaminants (Hg, Pb and Zn).
- **Nanofertilizers:** They can contain nano zinc, silica, iron and titanium dioxide, different core shell gold nanobars, QD etc. and they should approve the control release and improve its quality.
- **Nonherbicides:** The synthesis of a precise target herbicide molecule encapsulated with nanoparticles is targeted at a definite receptor in the roots of the target weeds, that penetrate the root system and shift to parts that inhibit glycolysis or other food reserve pathways in the root system. This will starve the specific weed and it will be killed.
- **Nano pesticides:** The recent development of a nonencapsulated pesticide formulation has a slow-release action with improved solubility, specificity, permeability and stability. A range of formulation types have been suggested including emulsions, nano capsules and nano clays. These products can be used to improve the effectiveness of use of the active ingredients of existing pesticides or to improve sustainability.
- **Nanotechnology in food crop production and food safety:** These have developed a new plastic that prevents the penetration of oxygen as a barrier. Polymer silicate nanocomposites, nano coatings are fruit products that completely cover the fruit and prevent weight loss and fruit shrinkage. The development of smart packaging to optimize the shelf life of products has been the goal of many companies.

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## ABIOTIC STRESS RESISTANCE BREEDING IN OMICS AND CLIMATE CHANGE ERA: A REVIEW

Subhash Kumar<sup>1</sup>, Shri Kant<sup>2\*</sup>, Sandeep Kumar<sup>3</sup>, Everest Shiwach<sup>4</sup>  
and Seema Rani<sup>5</sup>

<sup>1</sup>Department of Botany, C.C.R(PG) College, Muzaffarnagar (U.P.), India

<sup>2</sup>Department of Ag. Botany, C.C.R(PG) College, Muzaffarnagar (U.P.), India

<sup>3,5</sup>Department of Botany, Meerut College, Meerut (U.P.), India

<sup>4</sup>Department of Botany, D.N. College, Meerut (U.P.), India

\*Corresponding Author E-mail– shrikant2704@rediffmail.com, subhashvikal2012@gmail.com

### ABSTRACT

Recent advances in Molecular biology, Genomics, Proteomics, Bioinformatics and Statistical tools (quantitative genetics), made it possible to dissect the genomic regions associated (QTLs/genes) with stress tolerance in food crops. The forward genetics tools like fine mapping, map based cloning, insertional mutagenesis and random mutations are also being used to unravel the genetic basis of phenotypic variations which lead to development of abiotic stress tolerance/resistance characters in crops. Today genome sequencing is very cost effective. Cost effective sequencing tools enable us to decode the sequences of coding regions of genome for different abiotic stress responses using microarray technology. Reverse Genetic approach with the help of advanced molecular biology tools such as RNAi, CRISPR/CAS genome editing, TIILLING, Antisense RNA etc. also simplify the decoding of the function of genes by analysing phenotypic variations due to different abiotic stresses. Further, bioinformatics tools help us to analyse the massive amount of data or information generated in last decade from 'omic' tools. This data provides a basis for identification of more functional genes, which could contribute directly to cellular drought stress tolerance/ resistance.

**Keywords:** Abiotic stress, Genomics, Climate change, Stress tolerance varieties

### INTRODUCTION

As a consequence of global population growth, food demand has increased, and sustainable agriculture should be promoted to address the issues of climate change. Extreme weather events affect crop yield and food production, which exert harmful effects on the agronomic industry and lead to increase the demand for agricultural products (6,7). Food

security is facing large global and regional risks owing to climate change and increasing food demand. Thus, food production is an important aspect of food security. Major abiotic stresses, including drought, extreme temperatures, and salinity, cause extensive losses in agricultural production.(9)

Unraveling the genetic, molecular and physiological mechanisms or biochemical

pathways involved in abiotic stress tolerance by integrating different omics (phenomics, genomics, proteomics, metabolomics) with bioinformatics tools is very crucial in developing abiotic stress tolerant/resistant varieties. To understand the complexity of drought by dissecting genetic nature and action (including pleiotropy if any) of the QTLs/genes identified through QTL mapping/ other approaches is very crucial. Biotechnological and Genomic advancement lead to genetic enhancement of various crops which is being carried out through transfer of QTLs/genes using different approaches like marker assisted selection (MAS), marker assisted recurrent selection (MARS), genome wide selection (GWS), genetic engineering/transgenics. In view of the remarkable progress in these areas in recent years, integration of biotechnological approaches like molecular breeding with conventional breeding along with different omics tools (particularly genomics and phenomics) should be the major emphasis in development of abiotic stress resistance crops. Further, linking biophysical and genetic models to integrate physiology, molecular biology and plant breeding helps in dissecting or unravelling the complex traits associated with the drought/heat/salinity/cold resistance and thus further to speed up the breeding programme to develop climate smart varieties with great resilience to abiotic stresses.

## CLIMATE CHANGE: A REAL THREAT

Human-induced climate change is affecting weather and climate extremes, causing more, and more severe, heatwaves, heavy precipitation, droughts and cyclones. If greenhouse gas emissions is not reduced globally, temperatures of 2°C will be exceeded and bringing climate catastrophe

(10). The IPCC Working Group III report limit global warming to 1.5°C above pre-industrial levels. As per United Nations Climate Change, Annual Report 2021, global greenhouse gas emissions must peak by 2025 and decrease by 45 per cent by 2030 to achieve global net zero emissions by 2050. Recently COVID-19 pandemic, inflation and Ukraine conflict impact our economies especially in respect of food and energy security. The climate change crisis is intensified year after year. Last year saw the escalation of extreme weather events across the globe, from hurricanes and cyclones to flooding and wildfires, with devastating consequences. 2021 was also one of the seven hottest years on record, with record-shattering temperatures in different regions of the world. The estimated losses from natural disasters in 2021 amounted to more than \$280 billion globally, 70 billion more than in 2020 and \$114 billion higher than in 2019. (23)The true costs of climate change are still hidden, from threats to food security as a result of drought to biodiversity loss from the destruction of nature. Between 702 and 828 million people in the world faced hunger in 2021. (10).

## ABIOTIC STRESS IN CROP PLANTS

Biotic and abiotic stresses are major limiting factors for food production globally. Management of these stresses are more challenging under the climate change scenario due to emergence of new strains of pathogens and insect-pests, and erratic nature of environmental factors. Earlier, conventional breeding, bi-parental linkage mapping, and MAS have been successfully demonstrated in various crops. There is an immense potential of genome editing for rapid breeding of climate resilient varieties resistant/tolerant to biotic and abiotic stresses. Nonetheless, the availability of an efficient CRISPR/Cas system, target gene selection, plant transformation, and off target mutants would be some

challenges in tetraploid crop.(19,20,21) Overall, designs of potato that apply genomics, particularly genome editing and genomic selection, and other omics are inevitable in the future. (14,15)

The process of plant responses to abiotic stresses is complicated due to the interactions between stressors and diverse molecular, biochemical, and physiological aspects. The development of plant tolerance to abiotic stress is considered a promising approach for increasing crop yields. Advances in Omics (proteomics, transcriptomics, genomics, metabolomics, lipidomics, and epigenomics etc.) especially genomics and genome editing have broadened the chances of crop improvement.(25,26) Crop plant improvement through genomics aided methods is helpful to shorten the breeding cycle for development of new varieties. Amid growing challenges posed by climate change, abiotic stresses impart serious consequences on the growth and development of plants. With serious concerns about reduction in the yield, it often fails in ensuring food security to the global population. Under such circumstances, it becomes imperative to adopt strategic policies regarding attainment of agricultural sustainability to fulfill the need of food for growing population.(16,17)

## CONVENTIONAL BREEDING FOR ABIOTIC STRESS TOLERANCE /RESISTANCE IN POTATO

Potato *Solanum* belongs to family Solanaceae, which contains over 2,000 species, of which nearly 235 are tuber bearing potato species, where 73% are diploids (2x), 4% triploids (3x), 15% tetraploids (4x), and 8% pentaploids (5x)/hexaploids (6x). The cultivated potato (*Solanum tuberosum* ssp. *tuberosum*) is tetraploid ( $2n = 4x = 48$ ). Over 40 traits are considered to be important in

potato breeding. Conventional breeding is a time consuming process mainly due to several years of field evaluation and clonal selection. Though, conventional breeding approaches improve progeny for desired traits by attributing it with natural phenotypic and agronomic traits. It involves identification of traits for combination and selection of elite varieties with such traits. Conventional breeding too play very important role to improves crop plants for yield, nutritional value, and biotic as well as abiotic stress tolerance.(8)

To utilize the diversity of genetic resources in plant breeding, the potentially useful resources must be screened, selected and evaluated. A tolerance evaluation method with consideration of plant phenotypes is the key to stress breeding.

## Screening techniques for abiotic stress tolerance

### Heat Stress

- *In vitro* tuberization
- Internodal elongation
- Nodal cutting tuberization assay
- Seedling assay

### Drought/ Water Stress

- Pulling resistance of root (PR)
- *In vitro* assay drought
- Electrolyte leakage bioassay salinity, drought, cold and heat

### Salinity Stress

- *In vitro* assay
- *In vitro* recurrent selection
- Hydroponic sand-based system

## Cultivation techniques for Heat Stress alleviation

- **Mulch:** Maintain soil temperature, reduce evapotranspiration
- **Intercropping:** Cool soil temperature, conserve soil moisture, reduce irradiance
- **Nutritional treatment:** Calcium and

Nitrogen Keep stomatal function, maintain cell membrane thermostability

- **Hormone treatment:** paclobutrazol (PBZ) Increase chlorophyll a and b content, increase net photosynthesis

### Cultivation techniques for Drought/ Water Stress alleviation

- **Irrigation scheduling:** Maintain water use efficiency (WUE) Kang *et al.*
- **Drip irrigation:** Maintain WUE Conserve soil moisture
- **Partial root-zone drying (PRD):** Increase WUE Jovanovic *et al.*
- **Mulch:** Enhance soil fertility properties, conserve soil moisture, reduce evapotranspiration
- **Application of Plant Growth Promoting Rhizobacteria (PGPR):** Enhance the ROS scavenging enzymes
- **Plastic film mulching:** Increase temperature and soil moisture, enhance

### Cultivation techniques for Salinity Stress alleviation

- **Irrigation management:** Increase water productivity
- **Application of silicon nanoparticle:** Increase the activity of antioxidant enzymes
- **Application of PGPR:** Enhance the ROS scavenging enzymes
- **Soil amendment using biochar:** Adsorb Na<sup>+</sup> and reduce Na<sup>+</sup> uptake

## MULTI-OMICS APPROACHES IN POTATO BREEDING

Functional genomics allows the mining of genes for trait of interest through transcriptome analysis like RNA sequencing and microarray. Besides structural genomics, other omics approaches are transcriptomics (genes), proteomics (proteins), metabolomics (metabolites), phenomics (high-throughput phenotyping), and ionomics (mineral ions). The aims of multi-omics approaches are to

acquire comprehensive and integrated understanding of biological processes (system biology) to identify various biological players/genes/regulatory elements underlying the traits like heat and drought stress. Numerous studies have been performed on transcriptomics in potato such as heat, drought, salinity, and nitrogen deficiency but limited work has been carried out on proteomics, metabolomics, and ionomics (1).

### Gene Mapping

Gene mapping is important for molecular breeding. The complex tetrasomic inheritance, acute inbreeding depression, and high heterozygosity of potato complicate its genetic mapping. Linkage mapping is the genetic association of traits with segregating alleles of molecular markers in a defined mapping population. The first linkage map was reported in 1988 using tomato RFLP (restriction fragment length polymorphism) markers in diploid species (*Solanum tuberosum*). (22) Then uncounted PCR-based molecular markers like Simple Sequence Repeat (SSR), Amplified Fragment Length Polymorphism (AFLP), and Diversity Array Technology (DART) were applied for mapping. Identification of tightly linked markers with a target gene for a trait is considered to be ideal for Marker Assisted Selection (MAS). MAS allows a significant decrease in field exposures by selection in the early stage, and thereby reduces field exposures and breeding cycles. (2)

### Genome Sequencing

In potato, a considerable number of linked markers have been developed and deployed for inherited traits like late blight, viruses, and potato cyst nematode resistance, yield, nutrient use efficiency, heat, drought, and cold stress etc. In 2011, the Potato Genome Sequencing Consortium (PGSC), formed by 26 international institutes belonging to 14 countries successfully deciphered the potato genome (840 Mb) containing 39,031

protein-coding genes using a homozygous doubled monoploid (DM 1-3 516 R44) of *Solanum tuberosum* ( $2n = 2x = 24$ ) (Potato Genome Sequencing Consortium, 2011).(3)

## CRISPR/Cas9 technology for genome editing

Genome editing is a noble technology to create new variation in the genome with desirable gene combinations. Earlier sequence-specific nucleases (SSNs) methods like Zinc Finger Nucleases (ZFNs) and Transcription Activator-Like Effector Nucleases (TALENs) were used. Now, Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR)/CRISPR associated protein 9 (Cas9) is the most widely used genome editing tool, which is an RNA-guided approach to target DNA/RNA sequences. CRISPR/Cas9 has revolutionized the plant research for multiple traits due to its ease in use, multiplexing capability, cost-effectiveness, and high efficiency.(11,12,13) Although, in potato highly heterozygous and tetrasomic inheritance have complicated its deployment but found effective for PVY resistance using CRISPR/Cas9 and CRISPR/Cas13a. Additionally, CRISPR/Cas9 has been demonstrated in potato for various other traits like coldinduced sweetening, glycoalkaloid content, homozygous mutants generation, acetochalactate synthase 1 and granule bound starch synthase genes (4)

The genome engineering tools have overcome challenges posed by traditional breeding approaches that led to shift from domestication to settled crop production system. CRISPR/Cas-mediated gene editing in one such approach emerged as major tool for enhancing tolerance of crop plants to different stresses. CRISPR/Cas system has evolved as a tool of high efficiency, specificity, time and cost effectiveness. The CRISPR/Cas system is preferred globally for deciphering gene

function for translational utility. The technique has been employed to diversify the crop improvement programs towards mitigation of abiotic and biotic stress challenges. The technique has also been employed to engineer plants for enhancing crop yield, nutritional value and disease resistance and critical traits for food security and sustainable agricultural growth.

Genetic diversity is the basic principal in breeding programs. Such diversity can be obtained from germplasm collection, plant introduction, landraces, hybridization, or modifications by mutation and genetic engineering. Landraces and wild relatives are the best genetic resources for breeding plants with biotic and abiotic stress tolerance, since they have been adapted in a wide range of habitats with harsh environments.

## Genomic Selection

Genomic selection (GS) or genome-wide selection or genomics assisted breeding is a strategy to predict breeding model at whole-genome level for both simple and complex inherited traits. Therefore, partitioning of genetic variance and genome wide prediction with allele doses is very important in tetraploid potato. GS allows the integration of phenotyping and HTG data of a training population (both genotyped and phenotyped) with a targeted breeding population (genotyped only) for the prediction of genomic models to select superior clones based on the genomic estimated breeding value (GEBV). GS accelerates the breeding cycle with an increase in genetic gain per unit time. Unlike animals and cereals, the application of GS is very limited in tetraploid potato and has been demonstrated recently for late blight and common scab resistance. The advancement in sequencing, softwares, HTG, HTP, and marker-trait association can reduce the breeding cycle from over 10 to as few as 4 years to increase the genetic gain in potato (5).

# High-Throughput Phenotyping

Conventional phenotyping is often slow, has limited phenotyping capability, and mostly relies upon destructive sampling. Hence, modern High-Throughput Phenotyping (HTP) or phenomics is an automated precision phenotyping system allowing identification of key traits associated with phenotypic variation under different growth conditions. HTP is usually based on automation, sensors, high resolution imaging cameras (RGB, multi/hyperspectral and thermal sensors), unmanned aerial vehicle (UAV) and robotics to record real-time images and hardwares/software to analyze data from field or controlled growth chamber. HTP enables measurement of phenotype, yield and its contributing traits, and physiological processes under stress such as photosynthesis, nutrient uptake and transport with precision and accuracy in a large set of genotypes with non-destructive sampling, for example the LemnaTec Scanalyzer 3D platform . HTP has been applied in potato for phenology study in field , heat and drought , drought , and canopy cover using UAV. (24)

**Table:1 List of varieties released in India indicating their main climate change related attributes (8)**

| S. No. | Potato cultivar | Heat tolerance | Drought tolerance | Late Blight tolerance |
|--------|-----------------|----------------|-------------------|-----------------------|
| 1.     | Kufri Pukhraj   | Sensitive      | High              | Medium                |
| 2.     | Kufri Jyoti     | Sensitive      | Medium            | Medium                |
| 3.     | Kufri Bahar     | Sensitive      | Medium            | Sensitive             |
| 4.     | Bhura Aloo      | Low            | Sensitive         | Sensitive             |
| 5.     | Kufri Chipsona  | Sensitive      | Medium            | High                  |

|     |                    |           |           |           |
|-----|--------------------|-----------|-----------|-----------|
| 6.  | Kufri Shinduri     | High      | Medium    | Sensitive |
| 7.  | Kufri Chandramukhi | Sensitive | High      | Sensitive |
| 8.  | Kufri Khyati       | Sensitive | High      | High      |
| 9.  | Kufri Megha        | Sensitive | Medium    | High      |
| 10. | Kufri Kanchan      | Sensitive | Medium    | Medium    |
| 11. | Kufri Arun         | Sensitive | High      | High      |
| 12. | Kufri Surya        | High      | Medium    | Sensitive |
| 13. | Kufri Thar-1       | High      | Sensitive | High      |

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## INFLUENCE OF ORGANIC MANURE AND BIOFERTILIZER ON FRESH WEIGHT AND DRY WEIGHT OF OKRA (*ABELMOSCHUS ESCULENTUS*)

Ankul Kumar<sup>1</sup> and Subhash Kumar<sup>2\*</sup>

<sup>1</sup>Department of Horticulture C.C.S. University, Meerut (U.P.), India

<sup>2</sup>Department of . Botany, C.C.R (PG) College, Muzaffarnagar (U.P.), India

\*Corresponding Author E-mail– subhashvikal2012@gmail.com

### ABSTRACT

Vermicompost is a slow releasing, organic manure which have most of the macro as well as micro nutrients in chelated form and supplement the nutrient requirement of plants for longer period. Generally, the vermicompost mixture contains 9.15 to 17.98 % Organic carbon, 1.5 to 2.50 % Nitrogen, 1.0 to 1.70 % Phosphorus and 1.4 to 1.6 % Potassium. Similarly bio-fertilizers help in improving biological activities of desirable micro- organisms in the soil and also improve the crop yield and quality of the produce. The micro- organisms like *Azotobacter* are considered important not only for their nitrogen fixing efficiency, but also for their ability to produce antibacterial and antifungal components and growth regulators. *Azotobacter* spp. is known mainly for their ability to produce plant hormones as well as polyamines and amino acids in culture, but they are also involved in the biological fixation of N and the increased activity of glutamate dehydrogenase and glutamine synthetase. Likewise, some phosphate solubilizing microbes like PSB are also found to be effective in improving phosphorus use efficiency.

**Keywords:** Vermicompost, Organic Manure, Biofertilizers, Dry Weight, Fresh Weight, Okra

### INTRODUCTION

Modern agricultural farming practices with extensive and irrational use of chemical inputs over the past few decades have resulted in several environmental hazards including loss of natural habitat, soil health problems like soil erosion, decreased groundwater level, soil salinization, pollution etc. due to fertilizers and pesticides, genetic erosion, ill effects on environment, reduced food quality and increased the cost of cultivation, rendering the farmer poorer year by year [1]. The continuous

use of chemical fertilizers resulted in the decline in organic matter content of the agricultural soil leading to depletion of beneficial microorganisms which in turn reduced the soil productivity(2). The agricultural land is diminishing exorbitantly and there is no scope for further expansion in area (3). Hence to meet the increasing demand, the crop production has to be increased per unit area of land. Organic agriculture is a holistic production management system which promotes and enhances sustainability. Organic Manures,

biofertilizers, and poultry manures are vital for sustainable agariculture production. (5) studied the INM on okra plants fertilized with recommended dose of NPK (100: 50: 50 kg ha<sup>-1</sup>) gave maximum plant height (104.42 cm), plant girth (3.18 cm), number of nodes per plant (15.07), and dry weight of the plant (53.77g), with least number of days to 50 % flowering (32.8 days), days to first picking (38.47days), maximum number of pods per plant (16.47), maximum pod length (17.07 cm), maximum pod weight (15 g), maximum pod yield per plant (238.33 g), maximum pod yield per plot (10.29 kg) and maximum pod yield (135.83 ha<sup>-1</sup>). (4) observed the effects of seed treatment with PSB on growth of okra and recorded increased percentage of germination, length of shoot and root, fresh and dry weight of plant, total chlorophyll and protein content as compared to untreated control. (7) maximum plant height, leaf area, number of nodes per plant, plant biomass-fresh weight, fruit length (16.45 cm), fruit girth (1.62 cm), single fruit weight (18.70 g) and fruit yield (228.38 q ha<sup>-1</sup>) of okra increased significantly with the application of FYM @ 10 t ha<sup>-1</sup> + 100 % NPK + vermicompost @ 5 t ha<sup>-1</sup> along with bio-fertilizers. (6) observed that application of FYM @ 25 t ha<sup>-1</sup> significantly increased growth, yield and quality attributes viz. number of leaves, number of branches and plant height, average number of fruit per plant, average fresh weight of fruit, fruit yield per plant and maximum average fruit yield per hectare was (16.25 t ha<sup>-1</sup>), maximum T.S.S and maximum ascorbic acid was (15.58 mg/100g) in okra fruits.

## MATERIALS AND METHODS

The present field experiment entitled “Effect of organic manures and bio-fertilizers on growth and yield performance of okra (*Abelmoschus esculentus* L. Moench) cv. Arka Anamika was conducted at the Horticulture Researches farm Department of Horticulture,

Chaudhary Charan Singh University, Campus Meerut (U.P) jayad season 2018-19. Physical and Chemical properties of soil of experimental are given in Table -1. Various treatments applied are given in Table-2 and design and layout of experimental field is given in Table-3.

**Table-1: Physical and Chemical analysis of soil of experimental field during 2019.**

| S.N | Soil characteristics                   | Value obtained | Method used                  |
|-----|----------------------------------------|----------------|------------------------------|
| 1   | Fined sand                             | 55.1%          | Hydrometer Method            |
| 2   | Silt                                   | 24.3%          | Hydrometer Method            |
| 3   | Clay                                   | 21%            | Hydrometer Method            |
| 4   | Texture                                | Sandy loam     | International pipette Method |
| 5   | Organic carbon                         | 0.44%          | Black's Method               |
| 6   | Total Nitrogen                         | 0.051%         | Subbiah Method               |
| 7   | Available Phosphorus                   | 0.078          | Olsen's Method               |
| 8   | Available Potash                       | 0.0201%        | Flame Photometer Method      |
| 9   | Zinc                                   | 0.009%         | Flame Photometer Method      |
| 10  | Boron                                  | 0.0022%        | Flame Photometer Method      |
| 11  | Molybdenum                             | 0.0012%        | Flame Photometer Method      |
| 12  | Ph                                     | 7.4            | Beckman's pH meter           |
| 13  | Electric Conductivity (EC) m. mhos./cm | 3.1            | Conductance Method           |

**Table -2: Treatment combinations: -**

| S.No | Notation       | Treatment              |
|------|----------------|------------------------|
| 1    | T <sub>1</sub> | Control                |
| 2    | T <sub>2</sub> | F.Y.M. @ 20 t/ha       |
| 3    | T <sub>3</sub> | Vermi Compost @ 5 t/ha |

|   |                |                                         |
|---|----------------|-----------------------------------------|
| 4 | T <sub>4</sub> | Poultry Manure @ 3.5 t/ha               |
| 5 | T <sub>5</sub> | F.Y.M. @ 20 t/ha + Azotobacter          |
| 6 | T <sub>6</sub> | Vermi Compost @ 5 t/ha + Azotobacter    |
| 7 | T <sub>7</sub> | Poultry Manure @ 3.5 t/ha + Azotobacter |

**Table-3: Design and Layout of the Experiment**

| Variety                          | Arka Anamika                        |
|----------------------------------|-------------------------------------|
| Design of layout                 | Randomized block design (RBD)       |
| Number of treatment              | 7                                   |
| Number of replication            | 3                                   |
| Number of plants per plot        | 15                                  |
| Plant distance                   | 40x50 cm <sup>2</sup> (Row x Plant) |
| Net plot size                    | 3 meter                             |
| Width of path                    | 1 meter                             |
| Width of main irrigation channel | 1 meter                             |
| Sowing time                      | 2 April                             |
| Width of experimental boarder    | 30 cm                               |
| Width of experimental field      | 150 cm                              |
| Length of experimental field     | 200 cm                              |
| Size of experimental field       | 630 meter <sup>2</sup>              |

Fresh weight of head of tagged plants was taken after removing soil from each plot and average weight of head per plant was calculated with the help of electronic weighing machine. Dry weight of plant was recorded at after harvest. Dry weight per plant of ten tagged plants were recorded at the time of harvesting.

## RESULTS AND DISCUSSION

The result of present investigation indicated that organic manures with or without bio-fertilizer increased fresh weight of plants and dry weight of plant. All the vegetative parameter is an important trait of biomass production. A healthy plant with sufficient leave have the ability to the efficient utilization of sunlight, water and nutrient for

better photosynthesis and biomass production. and better yield.

**Table-4 Effect of organic manures and bio-fertilizers on growth and yield performance fresh weight of plant (g) of okra (*Abelmoschus esculentus* L. Moench)**

| Treatment                               | Notation       | Fresh weight of plant (g) | Per cent increase over control |
|-----------------------------------------|----------------|---------------------------|--------------------------------|
| Control                                 | T <sub>1</sub> | 175.11                    | —                              |
| FYM @ 20 t/ha                           | T <sub>2</sub> | 228.46                    | 30.46                          |
| Vermi Compost @ 5 t/ha                  | T <sub>3</sub> | 288.36                    | 64.67                          |
| Poultry Manure @ 3.5 t/ha               | T <sub>4</sub> | 205.11                    | 17.13                          |
| FYM @ 20 t/ha + Azotobacter             | T <sub>5</sub> | 241.10                    | 37.68                          |
| Vermi Compost @ 5 t/ha + Azotobacter    | T <sub>6</sub> | 300.11                    | 71.38                          |
| Poultry Manure @ 3.5 t/ha + Azotobacter | T <sub>7</sub> | 220.10                    | 25.69                          |
| CD at 5%                                |                | 6.787                     |                                |
| SEm (±)                                 |                | 2.179                     |                                |

**Table 4.1.7 Effect of organic manures and bio-fertilizers on growth and yield performance dry weight of plant (cm) of okra (*Abelmoschus esculentus* L. Moench)**

| Treatment                               | Notation       | Dry weight of plant (g) | Per cent increase over control |
|-----------------------------------------|----------------|-------------------------|--------------------------------|
| Control                                 | T <sub>1</sub> | 45.12                   | —                              |
| FYM @ 20 t/ha                           | T <sub>2</sub> | 65.68                   | 45.56                          |
| Vermi Compost @ 5 t/ha                  | T <sub>3</sub> | 75.56                   | 67.46                          |
| Poultry Manure @ 3.5 t/ha               | T <sub>4</sub> | 60.43                   | 33.93                          |
| FYM @ 20 t/ha + Azotobacter             | T <sub>5</sub> | 70.85                   | 57.02                          |
| Vermi Compost @ 5 t/ha + Azotobacter    | T <sub>6</sub> | 80.24                   | 77.83                          |
| Poultry Manure @ 3.5 t/ha + Azotobacter | T <sub>7</sub> | 64.42                   | 42.77                          |
| CD at 5%                                |                | 0.518                   |                                |
| SEm (±)                                 |                | 0.166                   |                                |

Among all organic manures and bio-fertilizers the maximum plant weight (300.11) and dry weight of plants (80.24) were

recorded under a combination of organic manure and bio-fertilizer i.e. T<sub>6</sub> (VC@ 5 t/ha + Azotobacter) followed by treatment T<sub>3</sub> (VC@ 5 t/ha). The findings study confirmed with the finding of (7), (5), (4) and (8). FYM and VAM also seems as effective fertilizer to increase vegetative growth of okra.

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