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OPTIMIZING LITCHI PRODUCTION THROUGH INTEGRATED SHOOT PRUNING AND POTASSIUM SPRAYS

Ratna Rai^{*1}, Mitali¹, Yesh Pal Singh², Anil Chandra³,
Pratibha¹, Gopal Mani¹, Nitin Panwar¹, Rakhi Gautam¹ and Shambhavi⁴

¹Department of Horticulture (Fruit Science), College of Agriculture,
GBPUA&T, Pantnagar, U. S. Nagar, Uttarakhand-263145

² KVK, Muzaffarnagar-II, Meerut, Uttar Pradesh,

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⁴College of Agriculture, GBPUA&T, Pantnagar, U. S. Nagar, Uttarakhand-263145

***Corresponding Author E-mail**—ratnarai1975@gmail.com

ABSTRACT

Litchi (*Litchi chinensis*) is a subtropical evergreen fruit tree that requires specific environmental and physiological conditions to induce flowering. The process of flowering in litchi is regulated by a combination of genetic, hormonal, environmental factors and cultural management practices. Early post-harvest pruning combined with the application of nutrients like KNO_3 can enhance flowering by promoting the development of mature shoots and reducing winter flushing. The present experiment was therefore, conducted with the objective to study the influence of pruning intensity, pruning time and KNO_3 sprays on vegetative growth, flowering, yield and quality of litchi fruit cv. Rose Scented. The treatments included three factors: pruning time (29th June, 11th July, 23rd July and 4th August), pruning intensity (20 cm and 40 cm) and KNO_3 sprays (2% and 4%) which were compared against control. The findings revealed that early post-harvest pruning (29th June), combined with a pruning intensity of 40 cm and two sprays of 4% KNO_3 resulted in moderate vegetative growth, early fruit set, reduction in fruit drop and fruit burn while enhancing yield and fruit quality parameters in the next fruiting season.

Keywords: Litchi; Pruning time; Pruning intensity, Potassium Nitrate; Fruit quality

INTRODUCTION

Litchi (*Litchi chinensis* Sonn.), is a prominent evergreen fruit tree often known as the "Queen of fruits" due to its specific climatic requirement and fragile nature. Litchi originated in Southern China and is cultivated in few sub tropical countries of the world (16). The specific soil and climatic requirements

along with short life span of seed probably prevented rapid spread of litchi to other parts of the world. The important litchi growing countries of the world are China, India, Vietnam, Thailand, Bangladesh, South Africa and Nepal. China, India, Taiwan, Thailand and Vietnam are the top five countries producing litchi in the world (39). Globally, India is the second largest producer of litchi in the world

after China. In India, commercially predominant litchi areas falls in the Indo-Gangetic plains of Uttar Pradesh, Bihar, Uttarakhand and West Bengal, however, suitable climatic conditions in the sub-tropical states of Punjab, Himachal Pradesh and Jammu and Kashmir has further expanded its area of cultivation (32). India produces approximately 578 thousand metric tons of litchi annually which is cultivated over an area of about 98 thousand hectares, with a productivity of 7.43 metric tons per hectare (1). Bihar, West Bengal, Punjab, and Jharkhand are the major litchi-producing states in India. In Uttarakhand, litchi is grown on approximately 5,260 hectares, yielding around 18,710 metric tons each year (1).

The litchi requires dry and warm sub-tropical climate. Frost free winters and long hot summers with high rainfall and humidity are required for better flowering, fruit set and development (19). A cool weather condition is a prerequisite for flower induction in subtropical litchi (42). Winter temperature more than 25°C, favours vegetative growth rather than floral induction. Flower panicle initiation takes place when the temperature during swelling of the buds is 20°C or cooler (19). High atmospheric temperature i.e. more than 38 °C and low relative humidity i.e. less than 60% increases the incidence of fruit cracking (21).

In India, about 40 litchi cultivars are grown out of which around 12 or 13 are commercially cultivated. The same cultivar or variety is known by different names in various regions. In Uttarakhand, particularly the tarai belt of Udham Singh Nagar is dominated by the cultivar Rose Scented. The name is given due to distinct aroma of the fruits. The fruits are mostly oval or oblong-conical in shape, deep rose pink in colour and 20-24 g in weight. The pulp is soft, greyish white, very sweet, juicy with high TSS (29). Fruits are moderately susceptible to sunburn and cracking (6). The fruits are generally harvested during first to second week

of June and harvesting period lasts only for 10-12 days.

The flowering process in litchi is a complex interplay of environmental cues, genetic regulation, and physiological changes. It is greatly influenced by the cycle of shoot development (24). The maturity of terminal shoots plays a crucial role in floral initiation. If the terminal shoots reach maturity during the optimal inductive conditions, bud-break occurs late. Conversely, if they mature well before the ideal inductive stage, bud-break happens early, negatively impacting flowering. The litchi tree generally exhibits three vegetative flushes annually: the first early one occurs just after harvest, the second in the mid-year (August to October), and the third is the late flush (after November). Among these, the early and mid-year flushes significantly impact yield, while the late flush has negligible effect on yield (37). Removal of the late flush or new shoots developed in late winter has been reported to enhance flowering in litchi (4), suggesting that terminal shoots must mature sufficiently during the optimal flowering period.

Pruning not only restricts excessive vegetative growth but also maintains a balance between vegetative and reproductive stage of a tree. The photosynthetic translocation towards the roots get enhanced which indirectly regulates flower bud formation and improves fruit size, fruit colour and fruit quality during the fruit development stage. Heavy pruning causes excessive vegetative growth, which results reduction in flowering and fruiting. Pruning just after harvesting has been found to be beneficial for improving flowering (9). The effect of pruning on flower bud formation and quality of fruits has been studied by various workers in different crops (12, 31 and 41). Number of panicles per branch increased in pruned trees of litchi cv. Kaimanain in Hawaii. (23)

Floral initiation is also being greatly influenced by foliar application of plant nutrients which is quite efficient and helpful to fulfill the nutrient requirement of the plant especially when nutrient uptake by the root system is restricted. Potassium helps in the cell division, synthesis and translocation of carbohydrates (3). Timely application of potassium and its availability results in better colour, flavour, fruit size, fruit weight and juice content in fruits. It also enhances resistance against various abiotic and biotic stresses in the plants and also has role in adjusting excessive vegetative growth by inhibiting nitrogen absorption and thereby encouraging floral initiation (22). Application of potassium fertilizer also helps in delaying the harvest time. In leaves, high potassium content in the month of November-December has been found to reduce vegetative growth and induce early flowering and fruiting (14). Considering the effect of pruning and KNO_3 in the reproductive and vegetative cycle of litchi, the following experiment was conducted to study the effect of pruning and KNO_3 sprays on vegetative growth, flowering, fruiting and quality attributes in litchi under *Tarai* condition.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at Horticultural Research Centre, Patharchatta, Pantnagar. Geographically, Pantnagar is situated in the *Tarai* region at the foothills of the Himalayas, at 29° N latitude, 79.3° E longitude, and an altitude of 243.84 meters above mean sea level. The region receives an annual rainfall of approximately 145 cm, with significant variations throughout the year. The rainy season begins in late June and lasts until September, with the majority of

precipitation occurring due to the southwest monsoon during this period. Pantnagar experiences considerable temperature fluctuations, with summer temperatures reaching a maximum of 42-45°C, while winter temperatures drop significantly to 2-4°C.

Experimental layout

Fifteen-year-old litchi trees cv. 'Rose Scented' planted at a spacing of 5×5 meters in square system, were selected for the experiment. All chosen trees were uniform in vigor and size. The trial was conducted using Factorial Randomized Block Design with three replications. The treatments involved three factors: pruning time (29th June, 11th July, 23rd July, and 4th August), pruning intensity (20 cm and 40 cm), and two foliar sprays of KNO_3 (2% and 4%), on 30th October and 2nd December along with control (Table 1). Each replication included one tree as a treatment unit. The foliar application of KNO_3 was carried out using a foot sprayer (Aspee Maruti foot sprayer, model MRI 8) during the early morning hours between 6:00 and 7:00 AM.

Vegetative characteristics

Tree height, trunk girth, tree spread and leaflet area

The height, trunk girth (at 20 cm above the ground level) and tree spread of the trees was measured with help of a measuring tape. Leaflet area was calculated by dividing the mean leaf area with the average number of leaflets per leaf. The tree spread was measured in both the directions i.e. East-West and North-South. The average tree spread was calculated by using the following formulae:

$$\text{Tree spread (m)} = \frac{(E \ W) \ (N \ S)}{2}$$

Time taken for fruit setting

The time taken for setting of the fruits in each treatment was recorded by counting the number of days from the date of female flower opening to date of fruit setting.

Fruit drop and Fruit burn

The fruit drop was calculated by subtracting average number of fruits harvested per panicle from the average number of fruits set initially. The fruit drop and fruit burn percentage was calculated by using following formula, respectively,

$$\begin{aligned} \text{Fruit drop (\%)} &= \frac{\text{Number of fruits dropped}}{\text{Number of fruits set initially}} \times 100 \\ \text{Fruit burn (\%)} &= \frac{\text{Number of fruits burn at the time of harvesting}}{\text{Total number of fruits at the time of harvesting}} \times 100 \end{aligned}$$

Yield

Yield per hectare was calculated by multiplying the yield obtained per tree (kg) and number of plants per hectare. The data was subsequently converted to quintal/hectare.

$$\begin{aligned} \text{Number of plants per hectare} &= \frac{10000 \text{ m}^2}{5 \text{ m} \times 5 \text{ m}} \times 400 \end{aligned}$$

$$\begin{aligned} \text{Yield per hectare (q/ha)} \\ = \text{Yield per tree (q)} \times \text{Number of trees/ha} \end{aligned}$$

Pulp, peel and seed weight

The aril (pulp), peel and seed weight was measured by using an electronic balance.

Sugars

The sugars were estimated according to "Lane and Eynon's method" as described by Ranganna (1986).

Statistical analysis

The experiment was laid out in Factorial

Randomized Block Design (FRBD) with three replications and one tree per replication was taken for the study. Differences between the treatments were subjected to analysis of variance (ANOVA) using OPSTAT statistical package (Sheoran et al., 1998). The significant differences were determined at 5% level of significance. The significance of variation among the treatments was observed by the "f" test.

RESULTS AND DISCUSSION

Tree height, trunk girth, tree spread and leaflet area

The data presented in Figure 1 & 2 showed that the time of pruning, pruning intensity and KNO_3 sprays significantly affected the tree height, trunk girth, tree spread, and leaflet area. The maximum tree height (4.05 m), was found in the treatment T_3 , where shoot pruning was done on 29th June with removal of apical 40 cm of terminal shoot and two sprays of 2% KNO_3 was done while trunk girth (62.00 cm) was found to be highest in the treatment T_{15} , where pruning was delayed to 4th August with higher pruning intensity (40 cm) and two foliar application of KNO_3 at lower dose (2%) was done. The maximum tree spread (4.80 m) was observed in control (T_{17}) as plants continued to grow vegetatively in the absence of pruning.

The leaflet area was maximum (32.409 cm^2) in the treatment T_4 where early pruning on 29th June was done with the removal of 40 cm terminal shoot and was coupled with higher dose of KNO_3 (4%) sprayed twice, while the minimum leaflet area was observed in control (19.054 cm^2). In the treatment T_4 , early pruning led to early formation of leaflets in the season which received sufficient time for expansion resulting in more leaflet area. The lowest values for tree height (3.183 m), was obtained in the treatment T_5 (pruning on 11th July along with removal of 20 cm terminal shoot and 2% KNO_3 spray), trunk girth (46.000 cm)

in T_6 (pruning on 11th July along with removal of 20 cm terminal shoot and 4% KNO_3 spray) and tree spread (3.717 m) in T_{13} (pruning on 4th August with removal of 20 cm terminal shoot and 2% KNO_3 spray), respectively.

Close observation of the data (Fig. 1) revealed that trees which were pruned early in the season just after harvesting was over (29th June) with removal of more biomass (40 cm) from apical portion increased the tree height even at lower KNO_3 concentration (2%). The trunk girth however significantly increased when pruning was delayed for 4th August with 40 cm removal of terminal shoot and lower dose of KNO_3 (2%) was sprayed. The maximum tree spread was found in control, when plants were left as such after harvesting of fruits. Early and heavy pruning with higher dose of KNO_3 provided ample time for leaflet growth. The variation in tree height, trunk girth, tree spread and leaflet area might also be due to the physiological and biochemical response of plants to prevailing weather conditions during vegetative growth after pruning. The above findings are in accordance with the results of Ingle *et al.* (2005) who recorded marked effect of pruning severity on height and growth of acid lime trees. Lal and Mishra (2007) also reported that the increase in shoot girth was lowest in the un-pruned trees of mango cv. Chausa, while significantly higher shoot girth was observed when heading back was done up to secondary branches. Shukla *et al.* (2007) in their study on ber cv. Kaithali, also noticed remarkable effect of pruning time and pruning intensity on vegetative growth of plants.

Time taken for fruit setting, fruit drop, fruit burn

The time of pruning, pruning intensity and KNO_3 spray showed variable results on the time taken for fruit setting, fruit drop and fruit burn (Table 2). The minimum time taken for setting of fruits (14.00 days), was in the treatments T_7 , T_{15} , and T_{17} (Table 1 Treatment details). Minimum fruit drop (maximum fruit retention)

was obtained in the treatment T_8 (82.850%) which was at par with the treatments T_4 , T_2 and T_{10} . The sun burning incidence was found to be unaffected with the treatments, however, minimum burning effect was observed in the treatment, T_8 (8.433%). The maximum time taken for fruit setting was observed in the treatment T_{10} (18.00 days), highest fruit drop in control (89.470 %) and maximum fruit burn in T_{11} (14.667 %), respectively. These findings are supported by the studies conducted by Gill and Bal (2006) who reported that the less severely pruned trees showed better fruit set and fruit retention in ber cv. Umran. Lal and Shukla (2008), however, recorded non-significant effect of pruning on fruit drop in case of litchi. Kumar *et al.* (2015) observed that the variety and time of shoot pruning directly affected the fruit set and fruit drop in Cashewnut. (45) observed that foliar application of 4% KNO_3 enhanced fruit set in mango. Combined application of paclobutrazol with KNO_3 in mangosteen significantly improved flowering and fruiting (Omran and Semiah, 2006). Fruit setting in mango was enhanced with foliar application of 3% KNO_3 and induced better fruit setting as compared to control (33). (26) also observed that the application of 4% KNO_3 minimized fruit drop in mango cvs. Tommy Atkins, Heidi and Kent.

Yield

The yield (Table 2, Fig.3) is one of the most important parameter for deciding efficacy of any treatment. It was found to be significantly influenced by cultural practices like pruning and KNO_3 sprays. The maximum yield in our study (211.77 q/ha) was obtained in the treatment T_4 where early pruning on 29th June was done along with 40 cm removal of terminal shoots followed by two sprays of 4% KNO_3 on the newly developed shoots. The yield reduced drastically in the treatment T_{15} (73.91q/ha), where pruning was delayed to 4th August, the shoot removal was higher (40 cm) and lower dose of KNO_3 was sprayed. The emergence of new shoots in this treatment was

late and probably they did not get sufficient time for becoming mature enough for the formation of panicles in the subsequent fruiting season. Most of these shoots continued to give vegetative flush at the time of panicle emergence. Early pruning has been reported to increase yield in ber (8) and grape (7). Similarly impact of pruning severity has been observed in acid lime (10) ber (36), litchi (18), guava (15), mango (Singh *et al.*, 2010) and apple (11).

Quality parameters of litchi fruits

The pruning time, intensity and KNO_3 sprays could not exert marked effect on peel and seed weight, and reducing and non

reducing sugars (Table 3). The maximum pulp weight (16.340 g), and total sugars (14.073 %) was obtained in the treatment T_4 (pruning of 40 cm terminal shoot on 29th June with 4% KNO_3 spray). The fruits obtained from the control trees recorded minimum values for pulp weight (10.987g) and total sugars (12.697 %). The impact of pruning time and severity on fruit quality characteristics have been observed in guava (15; 2;), peach (37; 27, nectarines (44), phalsa (5), apple (34), mango (28) and litchi (20). (22) in litchi and (45), and (43) in mango observed that KNO_3 sprays did not significantly affect the quality.

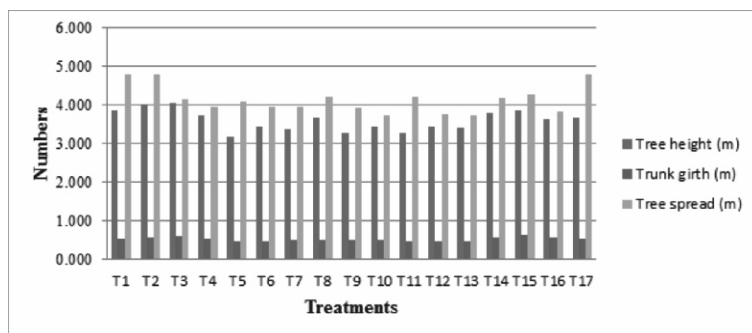


Fig. 1 Effect of pruning and KNO_3 spray on vegetative parameters of litchi

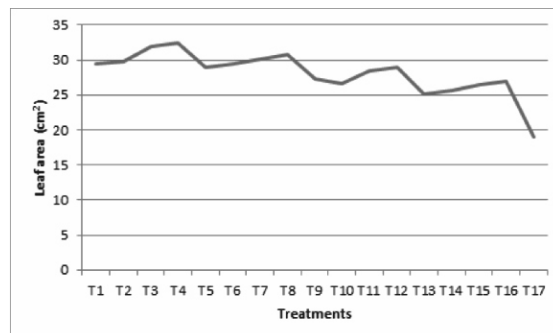


Fig. 2 Effect of pruning and KNO_3 spray on leaf area in litchi



(a)



(b)

Fig. 3 Effect of 40 cm shoot pruning done on 29th June and accompanied with two sprays of 4% KNO_3 : a. vegetative grown and flowering b. Fruiting

Table 1: Detail of Treatments

Treatments	Treatment detail
T ₁	Pruning on 29 June +removal of 20 cm terminal shoot + 2% KNO ₃ spray
T ₂	Pruning on 29 June +removal of 20 cm terminal shoot + 4% KNO ₃ spray
T ₃	Pruning on 29 June +removal of 40 cm terminal shoot + 2% KNO ₃ spray
T ₄	Pruning on 29 June +removal of 40 cm terminal shoot + 4% KNO ₃ spray
T ₅	Pruning on 11 July +removal of 20 cm terminal shoot + 2% KNO ₃ spray
T ₆	Pruning on 11 July +removal of 20 cm terminal shoot + 4% KNO ₃ spray
T ₇	Pruning on 11 July +removal of 40 cm terminal shoot + 2% KNO ₃ spray
T ₈	Pruning on 11 July +removal of 40 cm terminal shoot + 4% KNO ₃ spray
T ₉	Pruning on 23 July +removal of 20 cm terminal shoot + 2% KNO ₃ spray
T ₁₀	Pruning on 23 July +removal of 20 cm terminal shoot + 4% KNO ₃ spray
T ₁₁	Pruning on 23 July +removal of 40 cm terminal shoot + 2% KNO ₃ spray
T ₁₂	Pruning on 23 July +removal of 40 cm terminal shoot + 4% KNO ₃ spray
T ₁₃	Pruning on 4 August +removal of 20 cm terminal shoot + 2% KNO ₃ spray
T ₁₄	Pruning on 4 August +removal of 20 cm terminal shoot + 4% KNO ₃ spray
T ₁₅	Pruning on 4 August +removal of 40 cm terminal shoot + 2% KNO ₃ spray
T ₁₆	Pruning on 4 August +removal of 40 cm terminal shoot + 4% KNO ₃ spray
T ₁₇	Control (Neither pruned nor sprayed with KNO ₃)

Table 2: Effect of pruning and KNO₃ spray on time taken for fruit setting, fruit drop, fruit burn and yield of litchi fruits

Treatments	Time taken for fruit setting	Fruit drop (%)	Fruit burn (%)	Yield (q/ha)
T ₁	15.333	86.310	11.783	178.20
T ₂	15.667	83.115	14.487	191.87
T ₃	15.667	86.007	11.190	198.67
T ₄	16.667	82.884	11.260	211.77
T ₅	15.000	86.217	12.600	183.44
T ₆	16.000	83.440	8.433	192.25
T ₇	14.000	84.660	11.863	195.98
T ₈	15.333	82.850	13.800	204.80
T ₉	16.000	85.284	13.460	167.77
T ₁₀	18.000	83.936	11.400	178.61
T ₁₁	15.667	86.035	14.667	181.65
T ₁₂	16.667	85.745	14.633	194.41
T ₁₃	14.667	87.382	11.100	78.75
T ₁₄	15.000	85.493	12.733	81.15
T ₁₅	14.000	88.690	13.267	73.91
T ₁₆	15.333	86.319	8.833	87.28
T ₁₇	14.000	89.470	14.133	156.99
CD at 5%	1.520	2.771	NS	1.119
S. Em. ±	0.525	0.958	4.573	0.791

Table 3: Effect of pruning and KNO₃ sprays on quality characteristics of litchi fruits cv. Rose Scented

Treatments	Pulp weight (g)	Peel weight (g)	Seed weight (g)	Reducing sugars (%)	Total sugars (%)	Non-reducing sugars (%)
T ₁	14.023	2.547	3.120	9.750	13.213	3.463
T ₂	14.740	2.427	3.430	10.133	13.723	3.590
T ₃	14.753	2.603	3.280	9.870	13.360	3.490
T ₄	16.340	2.600	3.033	10.523	14.073	3.550
T ₅	12.687	2.477	3.290	9.893	13.433	3.540
T ₆	14.447	2.467	3.397	10.060	13.733	3.673
T ₇	12.923	2.333	3.343	10.420	13.863	3.443
T ₈	15.550	2.360	3.053	10.087	13.960	3.873
T ₉	12.943	2.373	3.010	9.897	13.353	3.457

T ₁₀	13.563	2.473	3.170	10.033	13.627	3.593
T ₁₁	12.463	2.587	3.180	9.840	13.383	3.543
T ₁₂	12.557	2.417	3.037	10.063	13.717	3.653
T ₁₃	12.023	2.637	3.293	9.960	13.443	3.483
T ₁₄	13.363	2.423	3.213	9.940	13.653	3.713
T ₁₅	13.983	2.400	3.310	9.903	13.503	3.600
T ₁₆	14.960	2.570	3.257	10.110	13.930	3.820
T ₁₇	10.987	2.703	3.473	9.440	12.697	3.257
CD at 5%	1.845	NS	NS	NS	0.486	NS
S. Em. $\pm$	0.638	0.165	0.198	0.239	0.168	0.203

CONCLUSION

The findings of present investigation indicated that 40 cm apical shoot pruning in litchi cv. Rose Scented done immediately after harvesting of fruits encourages development of new shoots which mature early and positively influence the fruit retention, yield and quality characteristics of fruits formed in the subsequent season.

The early pruning moderately controlled the growth of the trees as well. Two foliar applications of 4 % potassium nitrate on the newly emerged shoots maximized fruit yield and reduced fruit drop and sun burning in litchi. The time taken for fruit setting was also less in this treatment, which can be potentially applied for advancing harvest in time in litchi cv. Rose Scented under tarai conditions in the next season.

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EFFECT OF NUTRIENTS APPLICATION ON VEGETATIVE GROWTH, FRUIT QUALITY AND YIELD OF GUAVA CV L-49

Rakhi Gautam¹, Pratibha^{*2}, A.K. Singh³, Omveer Singh⁴,
Poonam Gautam⁵, S.C. Shankhdhar⁶, Ratna Rai⁷ and Yesh Pal Singh⁸

¹Ph.D. Scholar, ²Assistant Professor, ^{3,4&7}Professor, Department of Horticulture (Fruit Science),

⁵Professor, Department of Soil Science,

⁶Professor, Department of Plant Physiology,

G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India.

⁸SMS, KVK, Muzaffarnagar-II, SVPUA&T, Meerut, Uttar Pradesh, India

***Corresponding Author E-mail**—drpratibhahorti26@gmail.com

ABSTRACT

Guava which is an important fruit crop of India shows reduction in yield and quality production of fruits due to nutrients deficiency. Combined application of different macro (N, P, K and Ca) and micronutrients (zinc sulphate, ferrous sulphate, and boric acid) improve growth, yield and quality of the guava fruits. Considering the importance of nutrients application in guava, an experiment was carried out during the year 2022-23 on 11 years old guava trees planted at Horticulture Research Centre, Patharchatta, G.B. Pant University of Agriculture and Technology, Pantnagar. The experiment comprised of ten treatments as application of 25%, 50% , 75% and 100% recommended dose of fertilizers (RDF) combined with basal and foliar application of different nutrients *viz* zinc sulphate (100g and 1%), ferrous sulphate (100g and 0.5%), calcium chloride (100g and 0.5%) and boric acid (100g and 0.2%), respectively. The results of the study revealed that the highest plant height (4.63 m), stem girth (25.75 cm), canopy volume (173.29 m³), yield (31.91kg/tree), yield efficiency (0.69 kg/m³), fruit length (7.01 cm), fruit width (6.88 cm), number of fruits (197.33), fruit weight (227.61 g), total soluble solids (14.29°Brix) and ascorbic acid (272.15 mg/100g pulp) were obtained best with trees in which 75% RDF + 100g zinc sulfate + 100g calcium chloride + 100g ferric sulfate + 100g boric acid /tree/year was applied in the basin after pruning in June followed by two foliar sprays of 1% zinc sulfate + 0.5% calcium chloride + 0.5% ferric sulfate + 0.2% boric acid first just before flowering and second 30 days after the first application in last week of August and last week of September, respectively).

Keywords: Guava, nutrient application, growth, yield, fruit quality

INTRODUCTION

Guava (*Psidium guajava* L.) is one of the important fruit crop of tropical and sub-tropical region of India. It is commonly known as 'Apple of Tropics' or 'Fruit of masses' owing to its high nutritive value. It belongs to the family Myrtaceae and has a basic chromosome number of $x = 11$. The genus *Psidium* contains 150 species but only *Psidium guajava* is commercially cultivated. It is an important fruit crop of the nation. World's most wide spread nutritional disorders are caused due to diets lacking in vitamins and minerals and, therefore, guava has become a global priority in context to its health benefits. It has wider edapho-climatic adaptability, is hardy to various biotic and abiotic stresses, precocious and has prolific bearing habit. The fruit has high nutritive and medicinal value, and is used both as fresh fruit and after processing in different value added products. It is a good source of pectin, calcium, vitamins B12, vitamins C and vitamins A along with minerals like iron, calcium, and phosphorus. It also contains substantial quantities of carbohydrates and sugars. The conventional products of guava are jelly, jam, pulp, concentrate, juice, cheese, toffee, dehydrated guava and canned guava.

Optimum soil fertility and balanced nutrition plays an important role in enhancing production, quality and productivity of any crop (3). Use of different mixed and single micronutrients like, zinc sulphate, ferrous sulphate, copper sulphate, magnesium sulphate, manganese sulphate, boric acid play a very prerequisite role in promoting growth, yield and quality of fruits (6). Studies show that lack of zinc causes interveinal chlorosis, tiny leaf development, and "rosette" condition in guava or in other fruit crops as well. Deficiency of boron causes a major nutritional disorder "bronzing" in guava. This condition also appears when fruiting occurs in

Phosphorus and Potassium deficient environment, the nutrients from the elder leaves are transferred to the fruits, giving leaves bronze color. Deficiency of nutrients also leads to occurrence of many post-harvest diseases. Spray of CaCl_2 prior to harvest prevents preharvest fruit drop and reduces incidences of many post-harvest diseases (14).

Nutrients to the plant can be made available by the basal as well as by the foliar application. This deficit can be overcome by the application of such nutrients prior to flowering in the fruit crops (5). As we know that the inadequacy of one or other nutrients at critical stage of fruit development adversely affects the productivity and quality of produce (13), therefore, timely application and in appropriate concentration of fertilizers is important in order to provide maximum output. The present study was, therefore, undertaken in order to understand the influence of nutrients (both macro and micro) on growth, quality, and yield of guava.

MATERIALS AND METHODS

The present investigation was made during the year 2022-23 on 11 years old trees guava of cv L-49 at Horticulture Research Centre, Patharchatta, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, U.S Nagar, Uttarakhand. Pantnagar has humid subtropical climate having temperature ranging from 30°C to 43°C during summer and from 1°C to 10°C during winter.

All the trees taken under investigation were planted at 7 x 7 m distance in square system and maintained under uniform cultural practices during course of investigation. The experiment was carried out in Randomized Block Design with ten treatments replicated thrice and two plants per replication were taken. In total sixty trees were taken in the experiment. The details of treatments are given in table 1.

Table 1: Treatment detail of the experiment

Treatments	Treatment details
T ₁	Control: 100% RDF (450 g N: 400 g P ₂ O ₅ : 300 g K ₂ O + 50kg FYM) in the basin
T ₂	75% RDF + 100g each of zinc sulfate , calcium chloride , ferric sulfate and boric acid (basin) + One foliar spray of 1% zinc sulfate + 0.5% calcium chloride + 0.5% ferric sulfate + 0.2% boric acid
T ₃	50% RDF + 100g each of zinc sulfate , calcium chloride , ferric sulfate and boric acid (basin) + One foliar spray of 1% zinc sulfate + 0.5% calcium chloride + 0.5% ferric sulfate + 0.2% boric acid
T ₄	25% RDF + 100g each of zinc sulfate , calcium chloride , ferric sulfate and boric acid (basin) + One foliar spray of 1% zinc sulfate + 0.5% calcium chloride + 0.5% ferric sulfate + 0.2% boric acid
T ₅	75% RDF + 100g each of zinc sulfate , calcium chloride , ferric sulfate and boric acid (basin) + Two foliar sprays of 1% zinc sulfate + 0.5% calcium chloride + 0.5% ferric sulfate + 0.2% boric acid
T ₆	50% RDF + 100g each of zinc sulfate , calcium chloride , ferric sulfate and boric acid (basin) + Two foliar sprays of 1% zinc sulfate + 0.5% calcium chloride + 0.5% ferric sulfate + 0.2% boric acid
T ₇	25% RDF + 100g zinc sulfate + 100g each of zinc sulfate , calcium chloride , ferric sulfate and boric acid (basin) + Two foliar sprays of 1% zinc sulfate + 0.5% calcium chloride + 0.5% ferric sulfate + 0.2% boric acid
T ₈	75% RDF + Two foliar sprays of 1% zinc sulfate + 0.5% calcium chloride + 0.5% ferric sulfate + 0.2% boric acid
T ₉	50% RDF + Two foliar sprays of 1% zinc sulfate + 0.5% calcium chloride + 0.5% ferric sulfate + 0.2% boric acid
T ₁₀	25% RDF + Two foliar sprays of 1% zinc sulfate + 0.5% calcium chloride + 0.5% ferric sulfate + 0.2% boric acid

The recommended dose of fertilizers (RDF) and 100g each of zinc sulfate , calcium chloride , ferric sulfate and boric acid (wherever applicable) were applied in the basin in the last week of June (Fig.1). The first foliar application of 1% zinc sulfate + 0.5% calcium chloride + 0.5% ferric sulfate + 0.2% boric acid was done in the last week of August while the second foliar application was done in the last week of September (wherever applicable).

**Fig.1: Basal and foliar application of nutrients in guava orchard**

The height of the trees (Fig.2) was measured from the ground surface to the highest crown level with the help of a measuring pole. The trunk girth was measured with the help of tree calipers at the marked points in both the directions i.e. East-West and North-South and mean of both were recorded. The canopy volume was calculated as per the formula given by (15).

Fruit length and width (Table 2) were measured with the help of digital vernier calipers. The number of fruits were counted manually. The weight of the guava fruits was recorded with the help of electronic balance. Total soluble solids in fruit pulp was measured with the help of digital refractometer (0-85°B). The ascorbic acid content was calculated by reduction of 2,6-dichlorophenol indophenol dye by ascorbic acid as described by (9).

Yield per tree in kg (Fig. 3) was worked out by multiplying the total number of fruits on each tree by the average fruit weight at the time of harvest. The yield efficiency of each selected tree under observation was calculated as per the method given by (15).

RESULTS AND DISCUSSION

It is clear from the table and figures that for successful production of quality guava fruits, adequate supply of nutrients through application of optimum dose of fertilizers, at appropriate time is essential. Micronutrients like Fe, Zn, Mn, Cu and B help the plant uptake of major nutrients and play active roles in the plant metabolism like cell wall development, photosynthesis, chlorophyll formation, enzyme activity, nitrogen fixation and oxidation-reduction reaction. Guava responds significantly to applied micronutrients, especially zinc (Zn), boron (B), iron (Fe) and calcium (Ca) for improving growth, yield and quality.

Effect on vegetative growth

It is evident from the data presented in Fig. 2 that the maximum plant height (4.63 m), stem girth (25.75 cm) and canopy volume (173.29 m³) were obtained in the treatment T₅ (75% RDF + 100g each of zinc sulfate, calcium chloride, ferric sulfate and boric acid (basin) + Two foliar sprays of 1% zinc sulfate + 0.5% calcium chloride + 0.5% ferric sulfate + 0.2% boric acid) and the results were found to be *at par* with treatment T₆ and treatment T₈, whereas, minimum plant height (3.17 m), trunk girth (16.68 cm) and canopy volume (64.82 m³) was observed in control. Similar results were also recorded by (11) in guava while working on effect of organic and chemical fertilizers on guava. The workers reported that the increment in plant height, trunk girth and canopy volume might have been due to more absorption of nitrogen, phosphorus and potassium by plant, which

combined with carbohydrates in the leaves led to formation of more amino acids, proteins, chlorophyll and other amides. These effects increased the photosynthetic activity of the plants and resulted in greater synthesis of carbohydrates, which in turn favoured better growth and development of plants. Similar growth responses were also recorded by (1) in guava crop.

Effect on fruit quality

As evident from Table 2, the maximum fruit length (7.01 cm), fruit width (6.88 cm), number of fruits (197.33), fruit weight (227.61 g), total soluble solids (14.29°B) and ascorbic acid (272.15 mg/100g pulp) were obtained in the treatment T₅ (75% RDF + 100g each of zinc sulfate, calcium chloride, ferric sulfate and boric acid (basin) + Two foliar sprays of 1% zinc sulfate + 0.5% calcium chloride + 0.5% ferric sulfate + 0.2% boric acid) and the results were statically *at par* with treatment T₆ and treatment T₈ whereas, minimum fruit length (6.04 cm), fruit width (6.03 cm), number of fruits (138.33), fruit weight (132.65 g), total soluble solids (8.03 °B) and ascorbic acid (129.90 mg/100g pulp) was observed in control. Results of present study are in close conformity with the findings of (4) who reported that in rainy season guava fruits, application of microutrients increased the TSS content, ascorbic acid as along with increase in fruit size, fruit number and fruit weight. (10) also observed that the foliar sprays of boron improved the fruit quality which might have been due to better regulation of cell wall permeability, allowing more mobilization of water. Positive influence of micronutrients on fruit quality and yield in guava has also been reported by (12). They found that foliar application of zinc sulphate (1.0%) + boron (1.0%) resulted in maximum fruit width and highest fruit weight.

The best quality of fruits in terms of TSS, pectin content and ascorbic acid, was also recorded with zinc and boron in combination.

The increase in fruit quality might be due to better accumulation of carbohydrates, dry matter in fruits and increase in cell division, cell elongation and sugar metabolism. Boron and zinc have direct role in involvement of cell division, cell elongation and increased volume of intracellular space in mesocarpic cells. The workers also reported that pre-harvest sprays of 1.0% CaCl_2 led to an increase in the levels of calcium in the fruits, promoted 40% increase in ascorbic acid content, lowest weight loss (because Ca^{2+} ions increased cell wall stability by binding non-esterified pectins, increasing resistance to water flow, and making it hard for water to leave the cells) and rot incidence, thus can preserve the quality of the fruit and increase the nutritional value. (12) also studied the significant effect of foliar application of micronutrients such as zinc sulphate (0.5%, 1.0%), borax (0.5%, 1.0%) and copper sulphate (0.5%, 1.0%) on fruit set, yield attributes and yield of winter season guava cv. L-49 and observed similar results in terms of fruit set, fruit length, fruit width, and fruit yield.

Further combined application of micro and macronutrients increases the firmness, fruit diameter, TSS, vitamin C, yield per tree and reduced acid percentage. It also increases fruit weight, specific gravity, fruit yield, fruit length, and fruit volume.

Guava responds significantly to applied nutrients, especially zinc (Zn), boron (B), calcium (Ca) and iron (Fe) for improving growth, yield and quality. Moreover, micronutrients are required by plants in comparatively lesser amount and thus, can be applied more safely through foliar spraying which offers the possibility of quick absorption in plant cells at time of maximum requirements by the plants (1).

Effect on yield and yield efficiency

It is clear from the results presented in

Fig.3 that the maximum yield (31.91kg/tree) and yield efficiency (0.69 kg/m³) was obtained in the treatment T₅ (75% RDF + 100g each of zinc sulfate, calcium chloride, ferric sulfate and boric acid (basin) + Two foliar sprays of 1% zinc sulfate + 0.5% calcium chloride + 0.5% ferric sulfate + 0.2% boric acid) which was closely followed by treatment T₆ and treatment T₈. Minimum yield (11.55 kg/tree) and yield efficiency (0.27 kg/m³), however, was recorded under control (100% RDF) and was significantly lower than all other treatments. Similar results have also been documented by (8) during their study on foliar application of zinc and boron on winter season guava (*Psidium guajava* L.) cv. Pant Prabhat. The researchers found that these nutrients increased the yield and quality of fruit which might be due to combined effect of foliar application of iron, zinc, calcium and boron which directly or indirectly, involved in fruit yield and their activity improved number of fruits per plant. The present findings are in close agreement with the results of (7) and (11) in guava which implies that the high dose of macronutrients (nitrogen, phosphorus and potassium) have better capability for CO₂ assimilation that leads to higher rate of synthesis and supply of carbohydrates in the plants which is further transported to the fruits thereby increasing its yield and yield efficiency. This increase might be due to more number of fruits per tree, increased fruit set, fruit retention and higher fruit weight ((2).

CONCLUSION

There are several nutrient deficiency problems in guava which limits its vegetative growth, quality and yield thus it becomes essential to correct these nutrient deficiencies. The best way to overcome such major issue is by application of combination of nutrients in appropriate concentrations by both basal and foliar methods at appropriate time.

The best results in the present investigation were obtained in the treatment T₅ (75% RDF + 100g each of zinc sulfate, calcium chloride, ferric sulfate and boric acid (basin) + Two foliar sprays of 1% zinc sulfate + 0.5% calcium chloride + 0.5% ferric sulfate + 0.2% boric acid) as compared to application of only RDF. Therefore, this treatment can be recommended to the farmers for getting early, high quality and remunerative fruit yield of winter crop of guava.

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Conflict of Interest

Authors has no conflict of interest of any type.

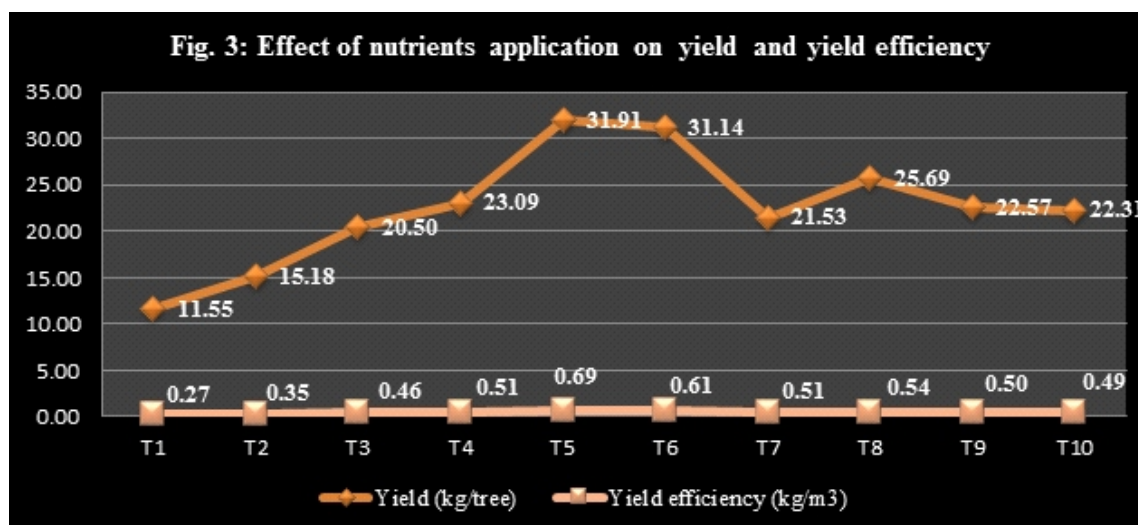
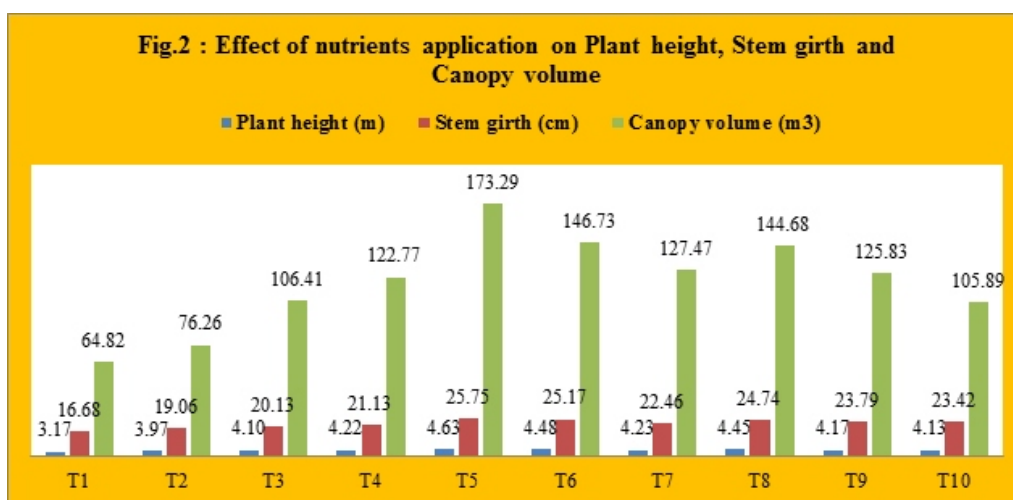


Table 2: Effect of nutrients application on fruit length, fruit width, number of fruits, fruit weight, total soluble solids and ascorbic acid of guava cv. L-49

Treatments	Fruit length (cm)	Fruit width (cm)	Number of fruits	Fruit weight (g)	Total Soluble Solids (°Brix)	Ascorbic acid (mg/100g pulp)
T ₁	6.04	6.03	138.33	132.65	8.03	129.90
T ₂	6.37	6.24	155.33	149.59	9.82	173.45
T ₃	6.46	6.34	163.33	162.44	10.39	191.30
T ₄	6.51	6.46	177.5	166.36	12.17	197.45
T ₅	7.01	6.88	197.33	227.61	14.29	272.15
T ₆	6.90	6.81	193.33	211.17	13.24	240.95
T ₇	6.54	6.51	186.67	188.17	11.45	206.50
T ₈	6.85	6.72	190.17	204.48	12.89	231.60
T ₉	6.56	6.46	183.33	174.81	11.15	220.05
T ₁₀	6.48	6.44	177.5	168.33	11.08	211.55
C.D. @ 0.05	0.31	0.31	10.04	23.97	0.91	16.14
SE(m)	0.10	0.10	3.35	8.01	0.30	5.39

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ASSESSMENT OF SOIL QUALITY USING A READY RECKONER FOR KEY SOIL PARAMETERS

Dr Ashok Kumar

Director Shri Ram College, Muzaffarnagar, Retd Professor Soil Science, SVPUAT Meerut, (U.P)

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

ABSTRACT

This study focuses on the development and application of a ready reckoner to assess soil quality based on key soil parameters: pH, Electrical Conductivity (EC), Organic Carbon (OC), Phosphorus (P), Potassium (K), Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn), and Bulk Density (BD). A regression-based scoring system was developed for each parameter, wherein higher scores reflected better soil quality. These individual scores were then aggregated to compute an overall soil quality score. The soil quality classification criteria developed by Cornell University, USA, served as the benchmark for interpreting the results.

INTRODUCTION

Soil health plays a critical role in sustaining agricultural productivity and ecological balance. Accurate and rapid assessment of soil quality is vital for notified land management decisions. The Soil Health Card (SHC) is a scientific tool designed to provide farmers with crucial information about the condition of their soil. It outlines the soil's physical, chemical, and biological properties and helps identify nutrient deficiencies that affect crop performance. Based on diagnostic results, the SHC offers specific recommendations in terms of constraints and their implications. Additionally, it may suggest soil amendments such as compost, lime, or organic manure to enhance soil fertility.

Soil Health Cards are issued to farmers every three years. These services are provided free of cost, with the financial burden borne by the government. However, several challenges hinder the effectiveness of the current SHC system. Delays in sample collection, laboratory analysis, and report distribution, combined with limited trust in the accuracy of

results, have created a gap between the intended purpose and actual implementation. Furthermore, the calculation of fertilizer recommendations often lacks precision.

The existing Soil Health Card format (illustrated in Fig. 1) mainly presents data related to chemical parameters such as pH, Electrical Conductivity (EC), and the availability of macro- and micronutrients. The card is typically divided into two parts: Part I contains details of the soil sample (location, farmer information, sampling depth, etc.) and Part II includes the laboratory test results.

Each parameter is reported with its value (column 3), unit (column 4), and a general rating as Low, Medium, or High (column 5), along with the normal or recommended range (column 6) for reference. However, the current card does not quantify these ratings in terms of a numerical score out of 100, nor does it provide an overall soil quality score. The absence of a holistic assessment metric renders the card less useful for farmers seeking clear guidance for land management decisions

Fig-1. Existing Soil health Card

Soil Health Card					
Soil Sample Details					
Date of soil sampling			15.6.23		
Khasra no			45		
Irrigation status			Irrigated (Bore well)		
Soil type			Clay loam soil		
Soil Test Report					
S. No	Parameter	Test Value	Unit	Rating	Normal Value
1	pH	7.5		Moderately alkaline	7.0 Normal
2	EC	0.3	ds/m	Normal	0-1dS/m
3	Organic Carbon	0.61	%	Medium	0.51-0.75 %
4	Available Phosphorus(P)	23.47	Kg/ha	High	23-57 Kg/ha
5	Available Potassium(K)	300.5	Kg/ha	High	145-337Kg/ha
6	Available Zinc (Zn)	1.15	Mg/kg soil	Sufficient	>0.6ppm
7	Available Iron (Fe)	5.75	Mg/kg soil	Sufficient	>4.5 ppm
8	Available Manganese (Mn)	3.5	Mg/kg soil	Sufficient	>2.0 ppm
9	Available Copper (Cu)	0.6	Mg/kg soil	Sufficient	>0.2ppm

The existing Soil Health Card currently in use primarily focuses on chemical parameters such as pH, electrical conductivity (EC), and the levels of major and micronutrients. While useful, it lacks a comprehensive assessment that includes physical and biological aspects of soil health, which are crucial for understanding overall soil quality and long-term sustainability.

To address the limitations of the existing Soil Health Card (SHC) system, an improved version was proposed by (2). This revised SHC integrates physical, chemical, and biological indicators to provide a more comprehensive and scientifically robust assessment of soil health. A set of comprehensive indicators was used to develop the new card, incorporating all three key categories—physical, chemical, and biological parameters. Furthermore, in this manual, a novel approach was introduced using a ready reckoner that correlates various soil properties with soil quality scores on a scale of 0 to 100, based on the selected indicators.

Key Parameters Selected for Modified Soil Health Card

In this study, Bulk density was chosen for physical parameters. Although several physical properties such as hydraulic conductivity, porosity, infiltration rate, moisture retention, and aeration are important determinants of soil health, bulk density (BD) was chosen as the **sole** physical indicator for the development of the Soil Health Card. This is because BD acts as an integrative parameter that reflects the combined effect of various physical characteristics. A higher bulk density often indicates soil compaction, reduced porosity, poor water infiltration, and limited root penetration, all of which negatively impact plant growth. Conversely, an optimal BD range suggests good soil structure, adequate pore space for water and air movement, and favorable conditions for root development and microbial activity. Through using bulk density alone, the complexity of physical soil assessment is simplified without significantly compromising accuracy. Thus, BD was considered a reliable proxy to represent the broader spectrum of physical soil health properties in the revised Soil Health Card.

Similarly, pH was included under chemical indicators in this new approach, as it reflects key soil characteristics such as soil reaction (salinity and alkalinity) and influences the behavior of various components present in the soil. Electrical conductivity provides insight into the type

and concentration of salts in the soil, thereby serving as an important indicator of soil quality. Phosphorus (P), Potassium (K), Iron (Fe), Manganese (Mn), Copper (Cu), and Zinc (Zn) are selected as essential nutrients that significantly influence plant growth and soil health. Whether present in deficient or excessive amounts, these elements can impact overall soil fertility and crop productivity.

Similarly, Organic Carbon (OC) was selected as a key biological parameter, as it reflects soil microbial activity, their functional efficiency, and indicates the nitrogen status of the soil. Each parameter is evaluated using ready reckoner based on critical thresholds. Scores are assigned on a scale (typically out of 100), reflecting the parameter's contribution to soil. An average of individual parameter scores is calculated to produce a single Soil Quality Index that classifies soil health into distinct categories. Specific constraints and suggested corrective measures for each parameter are also included. Top of Form Bottom of Form

The improved card (illustrated in Fig. 2) is divided into seven distinct sections, which include parameter values (Column 3), ratings derived from scoring functions (Column 4), and interpretation guidelines. Each scoring function is built on critical limits, above or below which plant growth and yield are adversely affected. The results obtained through this improved Soil Health Card are summarized in the results section as an overall soil health score. Moreover, if any parameter falls within a poor or toxic range, the associated constraints and their implications are also detailed, providing actionable insights into soil management and improvement.

To address this, the present study introduces a ready reckoner developed through regression models that correlate individual soil properties with an overall soil quality index.

Fig-2. Modified Soil Health Card.

Soil Health Card					
Soil Sample Details					Remark
Name of farmer & Mob No		Ashok Kumar. 9760466351			
Crop Grown-		Rice, Wheat, Mustard			
Irrigation status		Irrigated (Bore well)			
Soil Textural Class		Clay Loam			
Geo Position (GPS)		Latitude- N, Longitude- E, Altitude- MSL			
Soil Test Report and Quality Score					
Group	Parameter	Test Value	Score	Category	Remark
Physical Property	Bulk Density (gm/cc)	1.24	84	High	
Chemical Property	pH	7.5	60	Medium	
	EC (ds /m)	0.3	60	Medium	
	Available Phosphorus (P kg/ha)	23.47	100	High	
	Available Potassium (K kg/ha)	300.5	75	high	
	Available Zinc (Zn)mg/kg soil	1.15	100	high	
	Available Manganese (Mn) mg/kg soil	3.5	95	high	
	Available Iron (Fe) mg/kg soil	5.75	100	High	
	Available Copper (Cu) mg/kg soil	0.6	43	Medium	
Biological Property	Organic Carbon (%)	0.61	80	high	
Overall quality score (out of 100				79.7(H)	

Explanation of Result: Soil is healthy and fertile, no significant issues observed. Suitable for growing all regional crops.

MATERIALS AND METHODS

Study Parameters

The ready reckoner incorporated the following soil parameters:

- **pH** – Indicator of soil acidity/alkalinity
- **Electrical Conductivity (EC)** – Measure of soil salinity
- **Organic Carbon (OC)** – Reflects organic matter content
- **Phosphorus (P)** – Essential macronutrient for plant growth
- **Potassium (K)** – Influences plant health and stress resistance
- **Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn)** – Micronutrients vital for enzymatic functions
- **Bulk Density (BD)** – Indicator of soil compaction and porosity

Development of Ready Reckoner

A set of regression equations (Table 1) was developed to quantify the relationship between each soil property and its corresponding soil quality score (Table 2 A,2B,2C). These equations were derived from empirical soil test data and calibrated to ensure that higher scores represent optimal or desirable levels of a given soil property, while lower scores indicate suboptimal or degraded conditions. Each soil property was evaluated using a standardized scoring scale, and the overall soil quality score was determined by calculating the average score across all parameters.

Table-1 Regression equation developed for various soil parameters and their respective score.

Soil Property	Soil Texture	Equation 1 (0- peak)	Range of X	Equation 2 (peak-0)	Range of X1
pH	Any Texture	$Y = 158.21x - 950.43$ $Y = 100$	6-6.65 6.65-7.25	$Y = -160x + 1259.6$, $Y = 100$	7.25-10
EC(d/m)	Any Texture	$Y = 100X + 30$	0.1-0.0.7	$Y = -100X + 180$ $Y = 100$	0.8-1.8 0.7-0.8
OC (%)	Any Texture	$Y = 118.17x + 8.06$ $Y = 100$	0.1-0.78 0.78-1.0	Not required	
Phosphorus (P kg/ha)	Any Texture	$Y = 6.74x - 33.78$ $Y = 100$	5-20 21-29	$Y = -5.8x + 273.85$	29-45
Potash (K kg/ha)	Any Texture	$Y = 0.2433X + 3.3352$	50-400	Not required	
Fe (mg/kg soil)	Any Texture	$Y = 18X + 32$ $Y = 100$	0-3.8 3.8-9	$Y = -18X + 266$	9 -14.75
Mn (mg/kg soil)	Any Texture	$Y = 24.87X + 15.59$ $Y = 100$	0-3.4 3.4-7.2	$Y = -27.85X + 300.36$	7.2-10.75
Cu (mg/kg soil)	Any Texture	$Y = 342.86X + 23.81$ $Y = 100$	0-.23 0.23-0.4	$Y = -400X + 260$	0.4-02.65
Zn (mg/kg soil)	Any Texture	$Y = 247X - 52.94$ $Y = 100$	0.1-0.62 0.62-1.2	$Y = -400X + 580$	1.2-1.45
BD (g/cc)	Sands, loamy sands	$Y = 75X - 24$	0.32-1.65	$Y + -148.32X + 332.67$	1.65-2.0
	Sandy loam, loams	$Y = 75X - 9$	0.12-1.45	$Y = 101.55X + 243.31$	1.45-2.4
	Sandy clay loam, clay loam	$Y = 75X - 9$	0.12-1.43	$Y = 100.44X + 239.76$	1.43-2.38
	Silt, silt loam	$Y = 82.39X - 8.93$	0.6-1.3	$Y = 87.09X + 214.92$	1.31-2.5
	Silt clay loam	$Y = 75X - 9$	0.12-1.43	$Y = 124.14X + 270.83$	1.44-1.8
	Sandy clay, silty clay	$Y = 103.79X - 18.72$	0.18-1.15	$Y = 66X + 175$	1.15-1.75
	Clay	$Y = 139.39X - 56.78$	0.75-1.1	$Y = 69.6X + 179$	1.11-1.55

Table-2(A). Ready Reckoner for scoring the soil test value to prepare the soil quality card

pH		EC ds/m		OC (%)		P (kg /ha)			
pH	Score	EC	Score	OC	Score	P	Score	P	Score
5	0	0	30	0.01	20	5	0	27	100
5.25	0	0.1	40	0.05	15	6	6	28	100
5.5	0	0.2	50	0.1	20	7	13	29	100
6	0	0.3	60	0.15	25	8	20	30	100
6.15	22	0.4	70	0.2	32	9	27	31	93
6.2	30	0.5	80	0.25	38	10	33	32	87
6.25	38	0.65	95	0.3	43	11	40	33	82
6.35	55	0.69	99	0.35	50	12	47	34	76
6.45	70	0.7	100	0.4	55	13	54	35	70
6.55	85	0.8	100	0.45	60	14	61	36	65
6.65	100	0.81	99	0.5	68	15	68	37	60
6.75	100	0.85	95	0.55	73	16	75	38	53
7	100	0.9	90	0.6	80	17	80	39	48
7.25	100	1	80	0.65	85	18	88	40	42
7.35	85	1.1	70	0.7	90	19	95	41	36
7.45	65	1.2	60	0.75	95	20	100	42	30
7.55	55	1.3	50	0.78	100	21	100	43	25
7.65	36	1.4	40	-	-	22	100	44	18
7.75	20	1.5	30	-	-	23	100	45	12
7.85	0	1.6	20	-	-	24	100	46	7
8.15	0	1.7	10	-	-	25	100	47	0
8.75	0	1.8	0	-	-	26	100	-	-

Table-2(B). Ready Reckoner for scoring the soil test value to prepare soil quality card

K (kg /ha)		Fe (mg /Kg soil)		Mn (mg/kg soil)		Cu (mg/kg Soil)		Zn (mg/kg Soil)	
K	Score	Fe	Score	Mn	Score	Cu	Score	Zn	Score
0	0	0	32	0	32	0	32	0.2	0
25	10	0.1	34	0.1	34	0.1	34	0.3	20
50	16	0.2	36	0.2	36	0.2	36	0.4	45
100	28	0.5	41	0.5	41	0.5	41	0.45	58
150	37	1	50	1	50	1	50	0.55	83
200	50	2	68	2	68	2	68	0.6	95
250	60	3	86	3	86	3	86	0.62	100
300	75	3.5	95	3.5	95	3.5	95	0.7	100
350	90	3.7	98	3.7	98	3.7	98	0.8	100
400	100	3.8	100	3.8	100	3.8	100	0.9	100
-	-	3.9	100	3.9	100	3.9	100	1	100
-	-	4	100	4	100	4	100	1.15	100
-	-	4.5	100	4.5	100	4.5	100	1.2	100
-	-	5	100	5	100	5	100	1.25	80
-	-	5.5	100	5.5	100	5.5	100	1.3	60
-	-	6	100	6	100	6	100	1.35	40
-	-	7	100	7	100	7	100	1.4	20
-	-	7.5	100	7.5	100	7.5	100	1.45	0
-	-	8	100	8	100	8	100	1.5	0
-	-	8.5	100	8.5	100	8.5	100	-	-
-	-	9	100	9	100	9	100	-	-
-	-	9.5	95	9.5	95	9.5	95	-	-
-	-	10	86	10	86	10	86	-	-
-	-	11	68	11	68	11	68	-	-
-	-	12	50	12	50	12	50	-	-
-	-	13	32	-	-	-	-	-	-
-	-	14	14	-	-	-	-	-	-
-	-	14.75	0	-	-	-	-	-	-

Table-3(C). Ready reckoner for scoring the soil test value to prepare the soil quality card.

Sands, Loamy sands		Sandy loam, loams		Sandy clay loam clay loam		Silt, silt loam		Silt clay loam		Sandy clay, silty clay		Clay	
BD	Score	BD	Score	BD	Score	BD	Score	BD	Score	BD	Score	BD	Score
0.32	0	0.12	0	0.12	0	0.1	0	0.12	0	0.18	0	0.4	0
0.4	6	0.2	6	0.2	6	0.2	7	0.2	6	0.4	24	0.45	6
0.5	13	0.3	13	0.3	7	0.3	15	0.3	13	0.5	34	0.5	13
0.6	21	0.4	20	0.4	20	0.4	24	0.4	20	0.6	44	0.6	27
0.7	28	0.5	28	0.5	28	0.5	32	0.5	28	0.7	54	0.7	41
0.8	36	0.6	36	0.6	36	0.6	40	0.6	36	0.8	64	0.8	55
0.9	43	0.7	43	0.7	43	0.7	48	0.7	43	0.9	74	0.9	70
1	50	0.8	51	0.8	51	0.8	56	0.8	51	1.0	85	1	83
1.15	62	0.9	58	0.9	58	0.9	65	0.9	58	1.15	100	1.1	100
1.25	70	1	66	1	66	1	72	1	66	1.25	92	1.2	95
1.35	77	1.1	73	1.1	73	1.1	80	1.1	73	1.35	86	1.3	88
1.45	84	1.2	80	1.2	80	1.2	90	1.2	80	1.45	78	1.4	80
1.55	88	1.32	90	1.32	90	1.3	100	1.32	90	1.55	72	1.5	74
1.65	100	1.45	100	1.43	100	1.4	93	1.43	100	1.65	66	1.6	67
1.66	86	1.55	86	1.45	96	1.5	84	1.44	91	1.75	60	1.7	60
1.67	84	1.65	76	1.55	86	1.6	75	1.45	90	1.85	53	1.8	53
1.77	70	1.75	65	1.65	75	1.7	67	1.5	84	1.95	46	1.9	46
1.87	57	1.85	55	1.75	64	1.8	58	1.6	72	2.05	39	2.0	39
2	35	1.95	45	1.85	54	1.9	50	1.7	59	2.15	33	2.1	32
2.1	20	2.05	35	1.95	44	2	41	1.8	47	2.25	26	2.2	25
2.2	6	2.15	25	2.1	29	2.1	32	1.9	34	2.35	20	2.3	18
2.24	0	2.25	15	2.2	18	2.2	24	2	22	2.45	13	2.4	11
-	-	2.35	5	2.3	9	2.3	15	2.1	10	2.55	7	2.5	4
-	-	2.4	0	2.38	0	2.4	6	2.18	0	2.65	0	2.55	0
-	-	-	-	-	-	2.5	0	0.12	0	-	-	-	-

How to Fill the Score in the Modified Soil Health Card

To ensure a standardized and science-based approach to evaluating soil quality, a Ready Reckoner (Table 2.A, 2.B, and 2.C) has been developed. This reckoner provides score values based on the results of soil testing for each parameter under study.

Each parameter included in the soil health card is carefully selected for its strong relationship with overall soil quality—such as pH, electrical conductivity, organic carbon, available NPK, micronutrients, and biological indicators (where applicable).

Steps to Fill the Soil Health Card:

1. **Refer to the Ready Reckoner Tables (2.A, 2.B, 2.C):** Use the soil test values of your sample and match them with the scoring scale provided in the tables.
2. **Assign the Score:** For each parameter, locate the score corresponding to the test value in the reckoner and record it in Column 4 of the soil health card.
3. **Calculate the Overall Score:** Once all parameter scores are recorded, calculate the average of all scores to obtain the overall soil quality score.
4. **Interpret the Results:** Refer to the Soil Health Interpretation Guide to understand the meaning of the overall score and individual parameter ratings (e.g., Low, Medium, High).
5. **Identify Constraints (if any):** If any parameter falls outside the optimal range and poses a constraint to crop production, refer to the section on “Agronomic Implications and Corrective Measures.”

Write the identified constraint and recommended management practices in the respective section of the card.

Soil Quality Classification

The classification of soil quality was guided by the Soil Health Assessment Framework developed by Cornell University, USA (Table-3). This framework classifies soils into categories such as:

Table 3. Quality score for individual quality parameter and overall soil quality

Individual indicator quality score			Overall quality score	
Score value (%)	Rating	Color ode	Score value	Rating
<30	Low	Red	<40	Very low
30-70	Medium	Yellow	40-55	Low
70-100	High	Green	55-70	Medium
			70-85	High
			85-100	Very high

Based on the soil categories proposed in the Soil Health Assessment Framework, the soil health score has been interpreted and presented after the results. Additionally, the new Soil Health Card includes identified constraints along with their implications, providing a more actionable and informative assessment of land management.

Soil Health Score Interpretation Guide

Normal Score Range (0 – 100)

1. Score: 70 – 100 (Good Soil Health)

- Soil is healthy and fertile.
- No significant issues observed.
- Suitable for growing all regional crops.

2. Score: 55 – 70 (Moderate Soil Health)

- Some properties are slightly below ideal conditions.
- Needs moderate corrective actions.
- Can support farming with attention to specific deficiencies.

3. Score: 40 – 55 (Poor Soil Health)

- Multiple properties are below satisfactory levels.
- Requires significant attention and amendments.
- Productivity may be limited without

improvements.

4. Score: Below 40 (Very Poor Soil Health)

- Unsuitable for farming in current condition.
- May have major issues like high compaction, poor structure, or nutrient imbalances.
- Needs substantial rehabilitation and corrective measures.

Abnormal Score Range (Above 100)

1. Score: 100 – 70 (But Above 100)

- **Warning:** Despite a high score, the soil may be **alkaline or saline**, or some **micronutrients may be in toxic ranges**.
- Requires immediate corrective actions before farming.
- May falsely appear fertile but can harm crop growth.
- May have issues like **compaction or looseness**.

2. Score: 70– 55 (Above 100)

- Several soil properties are beyond acceptable limits.
- **More constraints** than benefits.
- May have issues like **compaction or looseness, extreme alkalinity**, or **salinity**.
- Detailed soil testing and amendments are needed before cultivation.

3. Score: Below 40 (But Above 100)

- Soil is **unfit for farming**.
- May have issues like **excessive compaction or looseness, extreme alkalinity**, or **salinity**. Major amendments and expert intervention required.

Soil Constraints and Their Agronomic Implications

The soil quality card application identifies key constraints that negatively impact plant health, nutrient cycling, and overall soil productivity. These constraints arise when soil properties deviate significantly—either below or above—their optimal levels. Below are common soil constraints categorized by key soil parameters.

A. Constraints in Soils with Low pH (< ~6.0)

1. Nutrient Deficiencies

- Reduced availability of phosphorus, calcium, and magnesium.
- Molybdenum becomes less available.

2. Toxicity Risks

- Increased solubility of toxic metals (e.g., aluminum, manganese), which can harm roots and inhibit growth.

3. Poor Microbial Activity

- Acidic conditions suppress beneficial soil microbes, including nitrogen-fixing bacteria.

4. Reduced Crop Performance

- Most crops prefer a near-neutral pH; acidic soils often lead to stunted growth and lower yields.

5. Decreased Soil Structure

- Slower organic matter decomposition affects soil aggregation.

6. Liming Requirement

- Periodic lime applications (e.g., calcium carbonate) may be necessary to raise pH, increasing input costs

B. Constraints in Soils with Abnormally Low Electrical Conductivity (EC < 0.2 dS/m)

1. Nutrient Deficiency

- Indicates a lack of soluble nutrients like N, P, and K.

2. Poor Soil Fertility

- Often found in weathered, sandy, or excessively leached soils.

3. Low Crop Productivity

- Plants exhibit poor vigor, stunted growth, and chlorosis.

4. High Leaching Risk

- Excessive rainfall or irrigation can wash nutrients out of the root zone.

Constraints When Organic Carbon (%OC) Is Low

Organic carbon is vital for nutrient

retention, water holding capacity, and soil structure.

1. Poor Nutrient Retention

- Low CEC leads to reduced retention of K, Ca, Mg.

2. Reduced Phosphorus Availability

- P becomes fixed with Fe/Al (acidic soils) or Ca (alkaline soils) in the absence of organic matter.

3. Increased Potassium Leaching

- OC-rich soils hold K better, in low OC soils, K leaches easily.

4. Reduced Soil Fertility

- Lower microbial activity and beneficial soil organisms.

5. Degraded Soil Structure

- Compaction and crusting increase; root growth and infiltration are limited.

6. Lower Water Holding Capacity

- Soil dries out faster and lose nutrients through runoff/leaching.

D. Constraints When Available Phosphorus (P) Is Very Low

Plant Symptoms and Effects:

1. Stunted growth due to poor root development.
2. Purplish or dark green discoloration on older leaves.
3. Delayed flowering and fruiting.
4. Low seed and fruit yield.
5. Poor tillering in cereals like wheat and rice

E. Constraints When Available Potassium (K) Is Very Low

Plant Symptoms and Effects:

1. Yellowing or browning along leaf edges ("leaf scorch").
2. Weak stems leading to lodging.
3. Increased susceptibility to drought and disease.
4. Poor fruit and grain quality—affecting taste, storage, and shelf-life.

Other Notes:

- K is mobile in soil and prone to leaching, especially in sandy or low-CEC soils.
- Essential for enzyme activity, water regulation, and sugar transport.

F. Constraints Due to Low Micronutrient Availability**1. Iron (Fe) Deficiency**

- **Symptoms:** Interveinal chlorosis on young leaves.
- **Common In:** Alkaline, calcareous soils.
- **Impact:** Reduced chlorophyll, impaired photosynthesis.
- **Worsened By:** High bicarbonates, poor drainage, excess phosphorus.

2. Manganese (Mn) Deficiency

- **Symptoms:** Chlorosis with necrotic spots on younger leaves.
- **Common In:** Oats, wheat, barley, legumes.
- **Worsened By:** High pH, well-aerated sandy soils.

3. Copper (Cu) Deficiency

- **Symptoms:** Twisted leaf tips, bluish hue, dieback of terminal buds.
- **Impacts:** Poor pollen viability, weak stems.
- **Worsened By:** High organic matter soils; Cu tightly binds to organic matter.

4. Zinc (Zn) Deficiency

- **Symptoms:** Short internodes, interveinal chlorosis, white bands (in maize), “little leaf”.
- **Impacts:** Reduced growth, flowering, grain filling.
- **Worsened By:** High pH, excess P, sandy soils.

G. Constraints from Abnormal Soil Bulk Density**When Bulk Density is Too Low ($<1.1 \text{ g/cm}^3$)**

Common in organic, peaty, or freshly tilled soils.

1. Poor Seed-Soil Contact

- Impacts seedling anchorage and emergence.

2. Low Water Retention

- Requires more frequent irrigation.

3. Nutrient Leaching

- Loss of nutrients like nitrate and potassium.

4. Unstable Structure

- High erosion risk and potential collapse under machinery.

Soil Constraints and Associated Issues when key soil properties exceed optimal levels**A. Constraints in Soils with High pH ($> \sim 7.5\text{--}8.0$)****1. Micronutrient Deficiencies**

- Reduced availability of iron, zinc, copper, and manganese.
- Leads to chlorosis and poor plant development.

2. Phosphorus Immobilization

- Phosphorus binds with calcium, becoming insoluble and unavailable despite sufficient quantities.

3. Poor Crop Adaptability

- Many crops are not tolerant to alkaline conditions and show reduced vigor and yield.

4. Soil Salinity/Sodicity

- Alkaline soils are often associated with high sodium levels, compounding degradation issues.

5. Hard or Compacted Soil Structure

- Reduced drainage and aeration hinder root development.

6. Limited Microbial Activity

- High pH affects beneficial microbial communities, slowing nutrient cycling and organic matter breakdown.

B. Constraints in Saline Soils (High EC $> 4 \text{ dS/m}$)**1. Osmotic Stress**

- Salts reduce water uptake by roots, causing physiological drought.

2. Nutrient Imbalances

- Sodium, chloride, and sulfate interfere with the absorption of potassium, calcium, and magnesium.

3. Toxicity

- Sensitive crops may suffer from sodium and chloride toxicity, damaging roots and leaves.

4. Poor Germination

- Seeds may not germinate or produce weak seedlings under saline conditions.

5. Soil Structure Degradation

- Sodium disperses soil particles, causing crusting, poor aeration, and compaction.

6. Reduced Microbial Activity

- Salt-sensitive soil organisms decline, impairing fertility and biological health.

C. Constraints in Soils with Excess Organic Carbon (OC%)

1. Nutrient Imbalances

- High C:N ratio causes nitrogen immobilization.
- Micronutrients like Fe, Zn, Cu can be bound by organic matter and become unavailable.

2. Water Retention and Drainage Issues

- Peaty/high-OC soils may become waterlogged and poorly drained, increasing disease risks.

3. Temperature and Decomposition

- High OC slows spring warming and can intensify microbial nutrient losses (e.g., nitrogen leaching).

4. Soil Structure Challenges

- Very low bulk density leads to erosion risks and poor mechanical manageability.

5. Greenhouse Gas Emissions

- High OC can lead to increased CO₂, CH₄, and N₂O emissions, especially under saturation or heavy fertilization.

6. Management Difficulties

- OC-rich soils are unstable, soft, and difficult to work with, especially under wet conditions.
- Risk of land subsidence after drainage.

7. Interactions with pH and Salinity

- High OC buffers pH changes and may complicate liming or acidifying strategies.
- It may also influence salt binding and mobility.

D. Constraints in Soils with Excess Available Phosphorus

1. Agronomic Issues

- **Micronutrient Deficiencies**
- High phosphorus reduces uptake of Zn, Fe, and Cu (nutrient antagonism).
- Leads to chlorosis, stunted growth, and poor reproductive development.
- **Nutrient Imbalance**
- Excess P may cause inefficiency in nutrient use and hinder crop performance.
- **Suppressed Mycorrhizal Activity**
- High P can reduce mycorrhizal associations that assist with nutrient uptake.

2. Environmental Issues

- **Water Pollution and Eutrophication**
- P runoff promotes algal blooms, hypoxia, and fish kills in water bodies.
- **Soil Phosphorus Saturation**
- Once saturated, soils cannot retain additional P, increasing runoff/leaching risk.

3. Practical and Regulatory Challenges

- **Reduced Fertilizer Efficiency**
- Further P addition is economically wasteful and agronomically ineffective.
- **Regulatory Constraints**
- High P soils may be subject to restrictions or mandatory nutrient management plans.

E. Constraints in Soils with Excess Potassium (K)

1. Nutrient Imbalances

- **Magnesium Deficiency:** K competes with Mg, especially in sandy soils.
- **Calcium Deficiency:** High K interferes with Ca uptake, leading to quality issues like blossom end rot.
- **Reduced Nitrogen Use Efficiency:** Disrupts protein synthesis and grain quality.

2. Soil Chemical Imbalance

- High K skews the cation balance (K:Mg:Ca) and base saturation, impairing nutrient mobility and structure.

3. Crop Health Issues

- Lower fruit quality, sugar content, and shelf life.
- Excess vegetative growth at the expense of flowering or fruiting.

4. Environmental and Economic Concerns

- **Luxury Consumption:** Plants absorb K beyond need, wasting inputs.
- **Economic Loss:** Overuse leads to unnecessary expenses.
- **Leaching Risk:** K can leach in sandy soils, contributing to water quality issues.

Key Effects of Excess Micronutrients

1. Nutrient Antagonism

- High levels of one micronutrient may block uptake of others (e.g., Zn vs. Fe).

2. Toxicity to Plants

- Leads to leaf necrosis, enzyme inhibition, and poor growth.

3. Microbial Suppression

- High Zn or Cu can reduce beneficial microbial populations.

4. Environmental Hazards

- Micronutrient leaching may contaminate water and affect aquatic ecosystems.

5. Reduced Crop Yield & Quality

- Symptoms include poor fruit set, malformed seeds, and lower marketability.

Causes of Toxicity

- Overuse of micronutrient fertilizers or foliar sprays.
- Application of sewage sludge or contaminated manure.
- Industrial pollution or metal-rich irrigation water.
- Acidic soils increasing metal solubility.

Corrective Measures

- **Adjust pH:** Liming acidic soils reduces Fe, Mn, Zn, Cu availability.
- **Improve Drainage:** Reduces Fe/Mn toxicity in poorly aerated soils.
- **Follow Soil Tests:** Avoid excess

applications.

- **Balanced Fertilization:** Prevents antagonistic interactions.

- **Choose Tolerant Crops:** Some species tolerate higher metal levels better than others.

G. Constraints from High Bulk Density (Compacted Soils)

1. Restricted Root Growth

- Hard soil layers limit rooting depth and nutrient access.

2. Poor Infiltration and Drainage

- Increases runoff and waterlogging risk.

3. Oxygen Limitation

- Reduced aeration hinders microbial activity and root respiration.

4. Low Microbial Activity

- Compaction limits microbial populations, affecting soil health.

5. Nutrient Uptake Constraints

- Roots may not reach nutrients or water in compacted layers.

6. Yield Reduction

- Compounded effects lead to stunted plants and lower productivity.

Remedial Actions

- Avoid heavy traffic on wet soil.
- Use deep tillage or subsoiling to break compaction.
- Incorporate organic matter to improve porosity.
- Plant cover crops or deep-rooted species (e.g., radish) to enhance structure.
- Reduce tillage intensity over time to allow soil recovery.

RESULTS AND DISCUSSION

The developed ready reckoner allowed for rapid, semi-quantitative assessment of soil quality. Application of this tool across various soil samples revealed significant variability in soil health status. The scoring system effectively highlighted key nutrient

deficiencies and physical limitations, such as high BD or low OC content, that influenced the overall quality score.

The use of regression equations ensured that the scoring was data-driven and responsive to realistic field conditions. Furthermore, by adopting Cornell's soil health criteria, the tool aligns with internationally recognized standards.

CONCLUSION

The ready reckoner approach offers a practical, cost-effective, and time-saving method for evaluating soil quality using a select set of measurable soil properties. Its implementation can significantly assist farmers, agronomists, and land managers in diagnosing soil health and making data-driven decisions to enhance soil productivity and sustainability.

To further improve efficiency and accessibility, future developments could focus on region-specific calibration of the regression models and the integration of biological indicators, thereby enabling a more comprehensive assessment of soil health. Additionally, transitioning from a manual ready reckoner to a digital platform, such as a mobile or desktop application, would provide users with instant, precise, and user-friendly results. Such an application could empower

farmers with on-the-spot health analysis and tailored recommendations, reducing dependency on traditional laboratory testing and enhancing adoption at the grassroots level.

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IMPACT OF DIFFERENT PRUNING INTENSITIES, BIO-ENHANCERS AND BIOFERTILIZER APPLICATION ON YIELD AND ECONOMICS OF MANGO

Saurabh Tiwari and V. K. Tripathi*

Department of Fruit Science

Chandra Shekhar Azad University of Agriculture and Technology, Kanpur-208 002, U.P., India

*Corresponding Author E-mail—drvktripathicsa@gmail.com

ABSTRACT

An experiment was conducted over two consecutive years *i.e.*, 2023-24 and 2024-25, at Horticulture Garden, Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.), using ten treatment combinations involving pruning intensities, bio-enhancers and biofertilizer application in a randomized block design with three replications on sixteen-year-old mango plant. Results show a significant improvements across all yield and economic parameters using an integrated treatment, T₉-Retention of 20 cm + 30% Fruit Thinning + Panchgavya (3%) + *Azotobacter* (100g/tree), which consistently gave an outperforming impact over others. In yield traits, treatment T₉ also results in the production of the highest fruit yield of 5.15 tons/ha, when data of both years were pooled. Among the economic parameters, T₉ shows the highest cost of production with the amount of Rs. 39250.00/ha, along with the highest gross return of Rs. 128750.00/ha, maximum net return of Rs. 89500.00/ha, and along with a higher benefit-cost ratio of 2.28, during both years of experimentation in the plains of northern India.

Keywords: *Mangifera indica* L., Pruning intensity, Bio-enhancers, Cost of cultivation, Gross return, Net return and B: C ratio.

INTRODUCTION

Mango (*Mangifera indica* L.), a member of family Anacardiaceae, is one of the most important fruit crops in the tropics and subtropics, with over 1,000 recognized varieties worldwide (6). In India, it occupies 2,396,000 hectares with a production of 22,398,000 metric tonnes, making the country the global leader in mango cultivation and Uttar Pradesh ranks first in area and production (1). Clone 'Dashehari-51' being regular-bearing in nature is now widely cultivated for its attractive appearance,

fibreless flesh, excellent taste, and high export potential.

Despite of its commercial significance, mango productivity remains suboptimal due to an imbalanced canopy structure, poor nutrient use efficiency, and limited adoption of sustainable management practices. Pruning has been recognized as a vital orchard management tool for regulating canopy size, maintaining a balance between vegetative and reproductive growth, and improving flowering and fruit set (4). However, scientific information on the effect of different pruning intensities on mango yield and orchard

economics under North Indian conditions remains scarce.

In recent years, use of bio-enhancers and biofertilizers have gained prominence as eco-friendly alternatives to enhance soil health, improve nutrient availability, and increase crop productivity. Bio-enhancers, such as Amritpani, Jivamrit, and vermiwash, enhances microbial activity, organic matter decomposition, and nutrient mobilization, while biofertilizers supply essential nutrients through beneficial microorganisms (7, 9). Although their benefits in fruit, vegetable, and cereal crops are well-documented, systematic studies on their synergistic effects with pruning strategies in perennial fruit crops, such as mango, are limited.

Therefore, the present investigation was undertaken to assess the impact of different pruning intensities, bio-enhancers and biofertilizer application on yield performance and economics of mango. The study is expected to provide valuable insights into sustainable orchard management practices that enhance productivity, profitability, and resource-use efficiency in commercial mango cultivation in the plains of northern India.

MATERIAL AND METHOD

The presents experiment was conducted at the Horticulture Garden, Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.) over two subsequent years *i.e.*, 2023-24 and 2024-25. The Kanpur district is located at an elevation of 135 meters above sea level. It is situated in a subtropical zone with coordinates between 25.26° and 26.58° North latitude and 79.31° and 80.34° Eastern longitude. A total of ten treatment combinations were evaluated using a randomized block design with three replications, involving pruning intensities, bio-enhancers and biofertilizer application. The pruning was done in the month of June.

Observations Recorded

The following traits were recorded during the study:

Yield Traits:

Fruit yield (tons/ha): Fruits from each treatment was harvested at maturity and weighed. The yield per tree was recorded and converted to tons per hectare.

Economic parameters:

Cost of cultivation (₹ ha⁻¹): The cost of cultivation for different treatments was calculated by considering all expenses incurred during the cultivation of the experimental crop and adding variable costs due to the treatment.

Gross return (₹ ha⁻¹): The gross returns were calculated by multiplying the yield by the sale rate of produce. The sale rate was depicted based on the prevailing market rate of the produce.

Gross return (Rs./ha) = Selling price x Total yield

Net return (₹ ha⁻¹): The net income per hectare was calculated for each treatment by deducting the cost of production from the gross income obtained in each treatment.

Net return (Rs./ha) = Gross return – Total fixed cost

Benefit: cost ratio (B: C ratio): The benefit cost ratio was calculated as follows-

$$\text{B: C ratio} = \frac{\text{Net monetary returns}(\text{₹ha}^{-1})}{\text{Cost of cultivation}(\text{₹ha}^{-1})}$$

Table 1: Details of the experimental treatments

Symbols Used	Treatments
T ₀	Control (no pruning only water spray)
T ₁	Retention of 10 cm + 10 % Fruit Thinning + Amritpani (25%) + Azotobacter (100 g/tree)
T ₂	Retention of 10 cm + 10 % Fruit Thinning + Jivamrit (25%) + Azotobacter (100 g/tree)
T ₃	Retention of 10 cm + 10 % Fruit Thinning + Panchgavya (3%) + Azotobacter (100 g/tree)
T ₄	Retention of 15 cm + 20 % Fruit Thinning + Amritpani (25%) + Azotobacter (100 g/tree)

T ₅	Retention of 15 cm + 20 % Fruit Thinning + Jivamrit (25%) + <i>Azotobacter</i> (100 g/tree)
T ₆	Retention of 15 cm + 20 % Fruit Thinning + Panchgavya (3%) + <i>Azotobacter</i> (100 g/tree)
T ₇	Retention of 20 cm + 30% Fruit Thinning + Amritpani (25%) + <i>Azotobacter</i> (100 g/tree)
T ₈	Retention of 20 cm + 30% Fruit Thinning + Jivamrit (25%) + <i>Azotobacter</i> (100 g/tree)
T ₉	Retention of 20 cm + 30% Fruit Thinning + Panchgavya (3%) + <i>Azotobacter</i> (100 g/tree)

Application Schedule

Foliar sprays of bio-enhancers and bio-fertilizers were made before and after flowering during both years *i.e.*, 2023-24 and 2024-25. For the foliar spray on mango plants, such as to adequately drench the entire foliage, 10 litres of solution were used for spraying, which was done using a pneumatic foot sprayer fitted with a nozzle in the afternoon from 4:00 pm to 6:00 pm. For spraying on top of the plant, a high-legged stool was used to ensure that all sides of the plant were completely drenched. To prevent the spread of surplus spray under the plants, polythene sheets were placed on the soil to prevent spray drops from reaching the soil.

RESULTS AND DISCUSSION

Yield Parameter

Fruit yield (tons/ha): The perusal of data related to fruit yield presented in Table 4, clearly revealed that the maximum fruit yield of 5.15 tons/ha (from pooled data) was recorded in mango plants which were treated with the treatment of T₉-Retention of 20 cm + 30% Fruit Thinning + Panchgavya (3%) + *Azotobacter* (100 g/tree), followed by the treatment of T₈-Retention of 20 cm + 30% Fruit Thinning + Jivamrit (25%) + *Azotobacter* (100 g/tree) with the yield of 6.47 tons/ha in 2023-24, 3.36 tons/ha in 2024-25 and 4.91 tons/ha in pooled. The minimum fruit yield (3.59 tons/ha in 2023-24, 1.27 tons/ha in 2024-25 and 2.43 tons/ha in pooled) was recorded from the plants kept under control, where no pruning was done and only water

spray was made (T₀). Organic biofertilizers, such as Panchgavya, Jivamrit, and *Azotobacter*, enrich the soil with beneficial microbes, thereby enhancing nutrients absorption and improving plant resistance to diseases. Collectively, biofertilizers and bioenhancers improves nutrients availability, stimulate roots development, strengthen plant immunity and promote overall plant vigour, ultimately leading to increased fruit yield. These outcomes are consistent with the findings of (5) in papaya and (10) in mango.

Economic Parameters

The intensities of pruning intensities with different amount of bio-enhancers, and bio-fertilizers significantly influenced the cost of cultivation (₹ ha⁻¹), gross return (₹ ha⁻¹), net return (₹ ha⁻¹), and benefit-cost ratio (B: C ratio) during both years of production. The treatment of T₉-retention of 20 cm + 30% Fruit Thinning + Panchgavya (3%) + *Azotobacter* (100g/tree) consistently outperformed others across all traits.

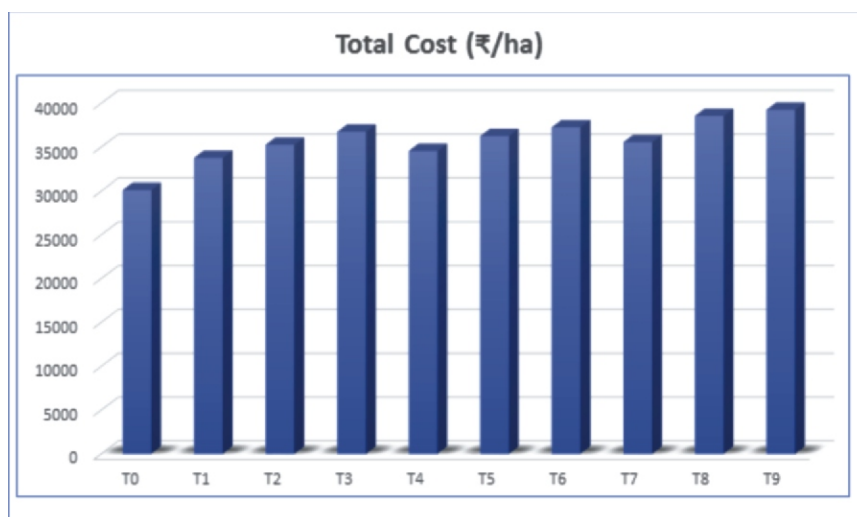
Cost of cultivation (₹ ha⁻¹): The cost of cultivation (Table 4) with the different pruning intensities and amount of bio-enhancers and bio-fertilizers applied for as per the treatments in the mango crop shows that the maximum cost of cultivation with the amount of Rs. 39250.00/ha, was calculated in the treatment of T₉-Retention of 20 cm + 30% Fruit Thinning + Panchgavya (3%) + *Azotobacter* (100 g/tree), followed by T₈-Retention of 20 cm + 30% Fruit Thinning + Jivamrit (25%) + *Azotobacter* (100 g/tree), which have the values of Rs. 38550.00/ha. The minimum cost of cultivation was recorded in the control, where no pruning was applied and only water was sprayed as in treatment T₀, which shows the cost of Rs. 30100.00/ha during both year of experimentation. These outcomes are in consistent with the findings of (8) in dragon fruit, (2) in strawberry.

Table 2. Total fixed cost of mango production (₹/ha)

Particulars	Unit and Frequency	Rate (₹)	Total fixed Cost (₹/ha)
Ploughing	1	2000/ha	2000
Cultivator	1	2000/ha	2000
Weeding	3 times × 4 labours	300/labour	3600
Irrigation (charges)	3 times	900/irrigation	2700
Irrigation (labour)	Labour (4)	300/labour	1200
Spraying	6 × 2 Labour	300/labour	3600
Pruning	2 × 2 Labour	300/labour	1200
FYM	10 Ton approx.	500/ton (avg)	5000
Harvesting	4 times × 2 labours	300/labour	2400
Packaging	4 times × 2 labours	300/labour	2400
Miscellaneous	—	—	4000
Grand Total			30100

Table 3. Impact of various pruning intensities, bio-enhancers and biofertilizer application on cost of treatments (₹/ha)

Symbols used	Treatments	Fixed Cost (₹/ha)	Variable Cost	Total Cost (₹/ha)
T ₀	Control (no pruning only water spray)	30100	-	30100
T ₁	Retention of 10 cm + 10 % Fruit Thinning + Amritpani (25%) + <i>Azotobacter</i> (100 g/tree)	30100	3650	33750
T ₂	Retention of 10 cm + 10 % Fruit Thinning + Jivamrit (25%) + <i>Azotobacter</i> (100 g/tree)	30100	5150	35250
T ₃	Retention of 10 cm + 10 % Fruit Thinning + Panchgavya (3%) + <i>Azotobacter</i> (100 g/tree)	30100	6650	36750
T ₄	Retention of 15 cm + 20 % Fruit Thinning + Amritpani (25%) + <i>Azotobacter</i> (100 g/tree)	30100	4450	34550
T ₅	Retention of 15 cm + 20 % Fruit Thinning + Jivamrit (25%) + <i>Azotobacter</i> (100 g/tree)	30100	6150	36250
T ₆	Retention of 15 cm + 20 % Fruit Thinning + Panchgavya (3%) + <i>Azotobacter</i> (100 g/tree)	30100	7150	37250
T ₇	Retention of 20 cm + 30% Fruit Thinning + Amritpani (25%) + <i>Azotobacter</i> (100 g/tree)	30100	5450	35550
T ₈	Retention of 20 cm + 30% Fruit Thinning + Jivamrit (25%) + <i>Azotobacter</i> (100 g/tree)	30100	8450	38550
T ₉	Retention of 20 cm + 30% Fruit Thinning + Panchgavya (3%) + <i>Azotobacter</i> (100 g/tree)	30100	9150	39250

**Fig. 1: Impact of various pruning intensities, bio-enhancers and biofertilizer application on cost of treatments (₹/ha)**

Gross return (₹ ha⁻¹): The gross return (Table 4) of different treatments with pruning intensities, bio-enhancers and bio-fertilizers was directly correlated with the yield of mango. The highest gross return *i.e.*, Rs. 128750.00/ha, was obtained in the treatment T₉-Retention of 20 cm + 30% Fruit Thinning + Panchgavya (3%) + *Azotobacter* (100 g/tree) followed by T₈-Retention of 20 cm + 30% Fruit Thinning + Jivamrit (25%) + *Azotobacter* (100 g/tree) which had the return of Rs. 122750.00/ha. The minimum gross return was obtained in control where no pruning was applied and only water was sprayed as in treatment T₀, with gross return value of Rs. 60750.00/ha. The gross return from mangoes increases with the increase in the doses of bio-enhancers and bio-fertilizers, due to increase in yield of quality fruits. These bio-inoculants enhance nutrient availability, improve plant health and reduce disease incidence, leading to more marketable produce and increased farmer profitability. These outcomes are in consistent with the findings of (3) in guava and (11) in strawberry.

Net return (₹ ha⁻¹): The net return (Table 4) of different treatments of pruning intensities, bio-enhancers and bio-fertilizers was calculated by subtracting the cost of cultivation by gross return. The highest net return was recorded in the treatment of T₉-Retention of 20 cm + 30% Fruit Thinning + Panchgavya (3%) + *Azotobacter* (100 g/tree) with the value of Rs. 89500.00/ha, followed by T₈-Retention of 20 cm + 30% Fruit Thinning + Jivamrit (25%) + *Azotobacter* (100 g/tree), which had the return of Rs. 84200.00/ha. The minimum net return was recorded in control where no pruning was applied and only water was sprayed as in treatment T₀, with the values of Rs. 30650.00/ha. These outcomes are consistent with the findings of (2) in strawberry, (3) in guava.



Fig. 2: Impact of various pruning intensities, bio-enhancers and biofertilizer application on gross return and net return (₹/ha)

Table 4. Impact of various pruning intensities, bio-enhancers and biofertilizer application on Economic parameters of mango (*Mangifera indica* L.)

Symbols used	Treatments	Cost of cultivation (Rs/ha)	Yield (t/ha)	Gross Return (₹/ha)	Net Return (₹/ha)	B:C Ratio
T ₀	Control (no pruning only water spray)	30100	2.43	60750	30650	1.01
T ₁	Retention of 10 cm + 10 % Fruit Thinning + Amritpani (25%) + + <i>Azotobacter</i> (100 g/tree)	33750	2.73	68250	34500	1.02
T ₂	Retention of 10 cm + 10 % Fruit Thinning + Jivamrit (25%) + <i>Azotobacter</i> (100 g/tree)	35250	2.87	71750	36500	1.03
T ₃	Retention of 10 cm + 10 % Fruit Thinning + Panchgavya (3%) + + <i>Azotobacter</i> (100 g/tree)	36750	3.36	84000	47250	1.28
T ₄	Retention of 15 cm + 20 % Fruit Thinning + Amritpani (25%) + <i>Azotobacter</i> (100 g/tree)	34550	3.10	77500	42950	1.24
T ₅	Retention of 15 cm + 20 % Fruit Thinning + Jivamrit (25%) + <i>Azotobacter</i> (100 g/tree)	36250	3.70	92500	56250	1.55
T ₆	Retention of 15 cm + 20 % Fruit Thinning + Panchgavya (3%) + <i>Azotobacter</i> (100 g/tree)	37250	4.30	107500	70250	1.88
T ₇	Retention of 20 cm + 30% Fruit Thinning + Amritpani (25%) + <i>Azotobacter</i> (100 g/tree)	35550	4.08	102000	66450	1.86
T ₈	Retention of 20 cm + 30% Fruit Thinning + Jivamrit (25%) + <i>Azotobacter</i> (100 g/tree)	38550	4.91	122750	84200	2.18
T ₉	Retention of 20 cm + 30% Fruit Thinning + Panchgavya (3%) + <i>Azotobacter</i> (100 g/tree)	39250	5.15	128750	89500	2.28

Benefit: cost ratio (B: C ratio)

The benefit-cost ratio of applying different pruning intensities, bio-enhancers, and bio-fertilizers to mango is presented in Table 4. The maximum B: C ratio was recorded in the treatment of T₉-Retention of 20 cm + 30% Fruit Thinning + Panchgavya (3%) + *Azotobacter* (100 g/tree) which had the ratio of 2.28, followed by 2.18 in the treatment T₈-Retention of 20 cm + 30% Fruit Thinning + Jivamrit (25%) + *Azotobacter* (100 g/tree). The lowest B: C ratio of 1.01 was recorded with the treatment T₀-control, where no pruning was applied and only water was sprayed. Thus, the results indicated that the pruning of plants with different intensity and use of bio-enhancers with bio-fertilizers increases mango yield, ultimately yielding a higher return for mango growers along with maintaining soil health. These outcomes are consistent with the findings of (8) in dragon fruit and (11) in strawberry.

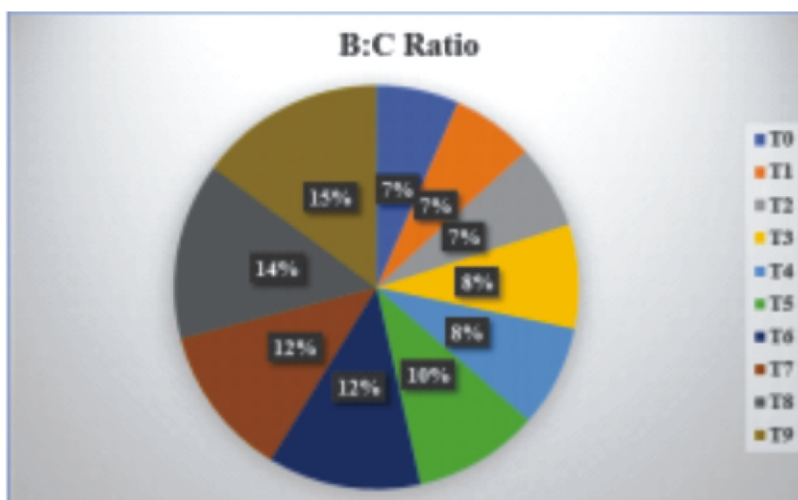


Fig. 3: Impact of various pruning intensities, bio-enhancers and biofertilizer application on Benefit: cost ratio

CONCLUSION

The study revealed that integrating pruning with bio-enhancers and biofertilizers use markedly improved both yield and profitability in mango cultivation. Among different treatments, treatment T₉-retention of 20cm pruning with 30% fruit thinning combined with the use of Panchgavya (3%) and *Azotobacter* (100 g/tree) consistently produced the highest fruit yield (5.15 tons/ha pooled), gross return (Rs. 1,28,750/ha), net return (Rs 89,500/ha) and benefit: cost ratio (2.28). This superiority can be attributed to improved canopy regulation, better nutrient uptake and enhanced plant vigour under integrated management. Hence, the findings emphasize that pruning, coupled with organic bio-inputs, offers a sustainable, profitable, and eco-friendly strategy for mango production, ensuring higher farmer income while maintaining soil health in the plains of northern India.

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VERMICOMPOST AND VERMIWASH: SUSTAINABLE BIOINPUTS FOR SOIL HEALTH AND CROP PRODUCTIVITY

Nindiya Bharti¹, Astha², Khushboo Sharma¹,
Sumati Narayan¹ and Farooq Ahmad Khan¹

¹Division of Vegetable Science, SKUAST-Kashmir, Shalimar, Srinagar (J&K) 190025

²Division of Horticulture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P) 474002

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

ABSTRACT

The overuse of chemical fertilizers has led to declining soil organic carbon and the destruction of beneficial soil organisms, highlighting the urgent need for sustainable alternatives. Vermicomposting, the biological process of composting organic waste using earthworms such as *Eisenia foetida*, offers a natural, eco-friendly, and cost-effective solution. This document details the methods of preparing vermicompost, including pit, heap, kacha pit, and portable vermibed techniques, and explains the key environmental parameters necessary for optimal composting. It also highlights the collection, properties, and agricultural benefits of vermicompost and vermiwash—a nutrient-rich liquid extract produced during the process. Vermicompost enhances soil fertility, increases microbial activity, improves soil structure and water retention, and boosts crop yields and resistance to pests and diseases. By recycling organic waste into high-quality organic fertilizers and biostimulants, vermicomposting supports sustainable agriculture, environmental conservation, and rural livelihoods, positioning it as an essential practice for modern organic farming.

Keyword: Vermicompost, Vermiwash, Soil fertility

INTRODUCTION

With the increasing use of chemical fertilizers, the amount of organic carbon in the soil is steadily declining, and the indiscriminate use of chemicals is also destroying soil organisms. Therefore, in order to sustain soil fertility and continuity in the future, organic fertilizers are desperately needed. Among organic fertilizers, vermicompost (earthworm compost) holds a unique space due to its easy preparation and high quality (4).

- **Vermicompost:** The organic matter like dung, straw, garbage etc. swallowed by the earthworm comes out in a ground state from its digestive system and is called earthworm compost. (8)
- **Selection of place for making earthworm compost Shady:** A moist environment is required. Therefore, earthworm compost should be made under a dense shady tree or under an airy thatched roof. While selecting the place, special attention should be paid to proper drainage and proximity to a water source.

- The right time to make earthworm compost is to make earthworm compost. Anyway, farmers brothers can make earthworm compost throughout the year. Can be made, but earthworms are more active at a temperature of 15-20 degree centigrade.
- **Selection of earthworm species:** Although many species are used in making earthworm compost. It is used, but for farmers the species 'Eiseniafoetida' is always suitable. Maintenance of this species is also easy.
- **Organic matter useful for making vermicompost-** In making earthworm compost all organic substances that can easily decompose are suitable. For this purpose, animal dung, crop residues, vegetable residues etc. are used. Generally, half dung and half garbage etc. are mixed to prepare a mixture as food material for earthworms.
- For making earthworm compost, the pit is constructed, usually 3-4 feet wide. A cemented pit of required length and 1.5-2 feet depth needs to be made. The floor (surface) of the pit is cemented with concrete. A hole is made in the pit for water drainage. To make it more effective, two pits are made together and holes are left in the middle wall, so that the earthworm can easily go from one pit to another.
- **Leaving earthworms in pits:** Put cow dung and crop residue in the prepared pits. Fill the mixture of 1:1 to almost the height of the pit. Spread this mixture 20-25 times. Let it rot partially by sprinkling water continuously for several days. Remove the upper layer of the heap and put 1000 earthworms (1 kg) in it at the rate of per square meter length so that the earthworms are again covered with the upper layer and immediately sprinkle water as per requirement on the pit and cover it with a wet jute sack. To maintain 40-50 percent moisture in the pit, sprinkle water daily as per requirement. In this way, earthworm compost is ready in six to seven weeks.

Heap method of making vermicompost-

- Construction of kacha floor as per requirement.
- Construction of a thatched shed or a permanent shed.
- A bed (pile) on the floor, 1 meter wide, as required long and 1.5 and 1.5 to 2 feet high.
- Use of partially decomposed dung and organic waste in a mixture (1:1).
- 1 kg Releasing earthworms per square meter.
- Covering the heap with wet jute sack or hay, straw etc.
- It takes 2 to 2.5 months for the compost to prepare.

Kacha Pit method



For making vermicompost, cow dung, manganese, dung, paddy straw, maize, millet straw, farm residues, dairy/poultry waste, dry and green leaves, grass, urban garbage, dry biogas slurry, industrial waste etc. are used. From this raw material, non-degradable materials such as stone, glass, plastic, ceramics and metal fragments are separated and large lumps of garbage are broken and leaves etc. are cut into 3"-4" pieces so that composting/decomposition takes less time. Before filling these materials in the vermicompost bed, they are made into heaps and sprinkled with water and kept for 15-20 days to rot so that it becomes half-decomposed.

As per requirement, the wet garbage is also turned over so that there is no heat in it. The above action is essential. Compost is made by filling this semi-digested waste in earthen pits or cemented beds made above the ground or transportable plastic beds and releasing earthworms in it. Generally the size of the pit bed is kept 3 X 1 X 0.5 meter. The waste is filled in the prescribed structure up to 50 cm height, after 3-4 days of which earthworms are released in it and after sprinkling water, it is covered with wet sacks. It is necessary to apply a coating of cow dung and soil on the bottom and inner walls of the earthen pits. The filled waste should be kept in compost for 30-40 minutes until it is ready. (6).

It is essential to maintain 40-50 percent moisture and 20-27 degree centigrade temperature. Also, to protect from strong sunlight, termites, ants, birds etc., arrangements should be made for curtains made of sacks, thatch and twigs/green net. Keep in mind that at least 20 percent cow dung should be included in the organic waste, which should not be fresh but should have been cooled for 3-4 days. For rapid decomposition, cow dung slurry or 50-100 grams of Trichoderma powder can be added and by adding 50-100 grams of Azotobacter and PSB powder, the product matures quickly and becomes more effective. Never use any type of insecticide while making compost, you can sprinkle charcoal to protect from red ants. (10).

Vermicompost is ready in 45-60 days, which is as odorless as tea leaves. After 45 days, sprinkling of water is stopped and the sacks used as lids are removed, as a result of which the upper compost dries up and the earthworms go down into the moisture. Then the dry compost on top is separated. After 4-5 days, the upper compost dries up again, which is separated from the top. In this way, the entire compost is removed in 3-4 times and finally the earthworms are left. By filtering

the dry compost through 3-4 gas-shaped sieves, earthworms, their eggs and decomposed material are removed. Keep in mind that while making or removing compost, do not use hoe, spade, hoe etc. The extracted compost can be dried in the shade and filtered and stored in a shady place. About 60-70 percent vermicompost is prepared from the filled waste. (9).

Portable Vermibed



1. Selection of site:

- The most important factor to be taken into consideration is locating a site under shade or artificially created shade.
- The site for construction of the vermibed preferable is chosen to the organic waste to be used.
- Soil surface of the site selection should be hard.

2. Preparation of Ground:

- Area selected must have the dimension of 6ft x 15ft.
- The area must be upland or elevated with a slope of 4" to 6" towards the drain so as to allow the liquid produced by the earthworms to accumulate in the pit.
- Sharp stones should also be removed to prevent the bed from being damaged.

3. Fixing poles on the site:

- The unfolded bed must be placed on the site to correctly mark the locations for fixing poles.
- Marking for digging is required along the pockets provided with the bed.

- Markings must be accurate.
- Holes with a diameter of 3" and depth minimum 18" should be dug at the markings made.
- Take 14 straight wooden-poles of 39" each.
- The top ends of the poles must be smoothened and rounded. Care to be taken that no pointed ends remain on the surface of the poles.
- Pole diameter should be maintained at around 1.5".
- Now the poles should be inserted in the holes.
- The poles should be fixed with 18" below the ground.
- Care to be taken that they should be at a height of 21" from the floor.
- A pit must be dug as shown in the picture to collect the vermiwash in a container placed in it.
- Vermiwash produced is collected via a pipe

4. Installation of Bed:

- Open the bed by choosing the vermiwash drain on the lower slope of the ground.
- Lift the bed from all sides opened vertically.
- Insert simultaneously pockets of the bed through the poles fixed.
- Move bed carefully down the poles till the bed surface touches ground completely.
- It should fit correctly and accurately as shown in the picture.

5. Partly decomposed waste:

- Sort the waste properly making sure that the hard substances are removed as earthworms are not friendly with hard material.
- Please note culture is extremely friendly with dung.
- It is advisable to use partly decomposed waste for better results.

6. Filling the waste:

- The garbage and dung should be placed in alternate layers.
- Put stored garbage in the first layer with 6"

thick.

- Place next layer of dung again with 6" thickness.
- Repeat this process once again.

7. Watering the contents:

- Water the contents placed in the bed.
- This process is required to remove the heat accumulated in the decomposed material as they do not function in extra heat.
- Keep watering the contents till you feel that the heat has been satisfactorily removed.
- It is likely that layers of decomposed material may settle down by 6 to 8" after pouring.
- Additional layer of dung can be added till the contents reach the height of the bed.

8. Important parameters:

- **Temperature:** It is preferred that the temperature be between 25-35°C for vermicomposting efficiency.
- In general warmer temperatures 20°C stimulate reproduction.
- **Aeration:** Earthworms cannot survive under anaerobic conditions.
- Excessive moisture combined with poor aeration conspires to cut off oxygen supply, thereby killing the worms quickly.
- Not only the worms deprived of oxygen, they are also killed by toxic substances like ammonia.
- Nevertheless, the worms operate best when ventilation is good and the material they are living in relatively porous and well aerated.
- **Moisture:** The decomposed material used must be able to hold moisture.
- As the earthworms breathe through their skin, moisture content less than 50% is dangerous.
- The ideal moisture content range for the materials is preferred between 70-80%.
- **pH:** Worms can survive in a pH level of 7 to 9.
- But most experts feel that worms grow best at a pH level of 7 or slightly higher.

- If the food source is alkaline, the pH rises above 7 and if the food is acidic, the pH drops below 7.
- The pH can be raised by adding calcium carbonate. The compost mix can be made acidic by introducing peat moss.
- **Salt and Urine content:** Worms are very sensitive to salts, preferring salt contents less than 0.5%.
- If animal wastes are used for composting, it contains excessive urine.
- As a result the decomposed material must be leached by watering or precipitation to reduce the salt and urine contents.

9. Letting earthworms in the bed:

- Once the bed has been cooled down, small basins of about 3" to 4" deep should be made from all the sides.
- The earthworms should be allowed to mix with the mix and then the basins must be closed.

9.1 Letting in the earthworms-food:

- After three days, repeat the process of making basins as mentioned above and place the earthworm-food and close the basins.
- Make sure that the heat generated is removed by watering the mixture frequently as earthworms require moisture to grow.
- Allow the earthworms to act upon the mixture for a period of 2 months.

10. Vermiwash:

- The liquid obtained from the outlet given in the bed is called as vermiwash.
- It is a mixture of the liquid ejected by the earthworm and excess water in the bed.
- The vermiwash produced should be collected in a container.
- It should be inspected properly.
- Vermiwash diluted with water can be sprayed on plants to function as an effective foliar spray and pesticide.

11. Visit and Observation:

- Earthworm-Manure, Earthworms and VERMIWASH should be inspected from

time-to-time.

- A constant check should be kept on the bed and the activities of the earthworms.
- The temperature of the bed should also be monitored from time to time as earthworms require a moist and cool temperature to grow and function.

12. Obtaining the manure:

- The manure will be completely ready in approximately forty days.
- Gather the produced manure from all sides of the bed.
- Stack a pile of the manure obtained.
- As a result, the earthworms are collected at the bottom leaving the manure at the top. It allows easy and efficient segregation of manure and the earthworms.
- The manure must be collected and sifted by using a sieve.

13. Packaging:

- Pack the sieved manure in bags.

14. Inspection:

- The manure produced should simultaneously be sent for inspection.

Collecting Vermicompost: After adding earthworms, the colour of the heap starts turning black and powdery in about six-seven weeks. When this stage is reached, watering of the pit is stopped. After four-five days, the earthworms move towards the moisture at the lower surface of the pit, hence the upper layer of the prepared manure is collected and taken out slowly in two-three times. The lower layer in which earthworms are present is collected at one place and the pit is again filled with a mixture of partially rotten cow dung and garbage and the lower layer of the prepared manure in which earthworms are present is left on the upper layer of the heap as before and the heap is covered with jute sacks. The earthworm compost taken out is filtered and filled in sacks and kept in a shady place till use. (2)

Properties of Vermicompost

A. Physical properties

- Earthworm compost is a granular, dark brown, black colored soft humus substance. It is free from foul smell, weeds and harmful bacteria.
- It increases air movement and water holding capacity in the soil and helps in drainage in heavy soils.

B. Chemical properties

- The chemical properties of earthworm compost depend on the quality of the raw material (organic matter) used in preparing it.

S.No.	Nutrients	Amount
Key Elements		
1.	Nitrogen	1.8 percent
2.	Phosphorus	2.0 percent
3.	Potash	1.4 percent
Trace Elements		
1.	Iron	21.6 (ppm)
2.	Zinc	12.7 (ppm)
3.	Manganese	19.2 (ppm)
4.	Copper	5.8 (ppm)

C. Biological properties

- The number of bacteria (Azotobacter, Phosphatesolubilizer and nitrobacter) – More than 10^{10}
- Actinomycetes – About 10^5 to 10^7
- Gibberellins, Auxins and Cytokinins - A variety of beneficial fungi in adequate quantities

Comparison of earthworm compost with DAP

S. No.	Description	Vermicompost	DAP (Chemical Fertilizer)
1.	Composting time	1.5 to 2.0 months, which the farmer can prepare himself on the farm.	It is prepared in the factory.
2.	Production	36 quintals/pit/pit filling work can be done three times in a year. ($3 \times 10 \times 1.5$ feet)	DAP production depends on the market requirement and factory capacity.
3.	Raw material	Animal dung and organic matter	Chemical substances

4.	Nutrients	Along with N.P.K,S,Fe,Zn,Me, B,Mn,Cu and other nutrients, organic acids are also obtained.	Only Na P
5.	Percentage of 5 main nutrients	Nitrogen - 1.8% Phosphorus - 2.0% Potash - 1.4%	Nitrogen – 18% Phosphorus – 46%
6.	Price	The farmer earns Rs. 1.25 per kg of earthworm compost. 10 quintals of earthworm compost is prepared for Rs. 1250/-.	One for Rs. 1250 Bags (50kg) of DAP are available from the market
7.	Availability of nutrients per Rs. 1250.00 spent	Nitrogen 18 kg. Phosphorus – 20 kg. Potash 14 kg Along with this all the nutrients are also available.	Nitrogen- 9 kg. Phosphorus – 23 kg
8.	Availability of 8 elements	Available for plants for 3 to 4 years.	For one crop only.
9.	The fertility potential of the soil	Along with increasing the fertility of the land, organic carbon is also supplied.	Only supply of nitrogen and phosphorus elements to plants.

Precautions in making Vermicompost

- Earthworm is sensitive to both low and high moisture, hence always maintain proper moisture (40-50 percent).
- Protect the heap from chickens, rats and termites. To protect from termites, use 4% neem insecticide or soak 500 grams of neem leaves in water overnight, grind them finely and mix them in one liter of water and spray.
- Do not put fresh dung on the bed because fresh dung generates heat which may cause the death of earthworms.
- Provide shade by making a platform over the pit and protect the pits from rain and flowing water.
- Do not allow water containing soap, medicines or any chemical to enter the pits.

- During the whole process, the upper surface of the bed must be howed twice, so that air circulation should remain smooth.
- Earthworms should be protected from frogs, snakes, birds, ants etc.
- The prepared earthworm compost should be kept in a shady place.

Use of Vermicompost

Vermicompostmanure is completely organic manure. With its use, not only the yield of the crop but also the disease and pest resistance capacity increases, there is exponential development in biochemical capacity (2). Amount of earthworm manure to be used: 3-5 tonne/hectare for food grain crops, 4-6 tonne/hectare for vegetable crops, 2-3 kg/tree for small fruit trees, 4-5 kg/tree for big fruit trees, 100-150 gram trees for pots, 2-3 kg/sq.metre for vegetable nursery.

Benefits of Vermicompost

- Vermicompost is a complete and balanced food/nutrition for crop plants, fruit trees, vegetables etc.
- Deteriorating soil fertility resulting from continuous and exorbitant use of chemical fertilizers can be Improved by the use of Earthworm compost.
- Humic acid, microbes and hormones found in earthworm compost. Regulate soil pH and Improves soil health,(including saline-alkali reclamation).
- Earthworm compost activates microbial population in soil, helps in keeping down weeds, pests and diseases by increasing resistant power and improving plant health resulting in increased yield.
- Earthworm compost helps plant to take macro and micro nutrients and preserves these nutrients.
- Increased water absorbing and holding capacity due to compost use in the field cuts short irrigation requirement.
- Multifarious influences of earthworm compost improve yield as well as the quality

and taste of the produces and helps fetching higher price.

- Safe disposal of organic waste/debris saves environment from pollution.
- Use of compost relives pressure on fertilizers and agro-chemicals and provides a safeguard against their ill effects on human health.
- Generate employment for rural youths and women.
- Increasing income through reduced input cost by saving expenses on chemical fertilizers and pesticides, irrigation and medical aid, additional employment and higher returns due to premium prices. (8)

Vermiwash (Worm-Tea)

Vermiwash is a liquid extract obtained from vermicomposting beds, rich in nutrients and beneficial microbes, making it an excellent organic fertilizer. (1)

Agriculturally Important Microbes in Vermiwash

Vermiwash contains various beneficial microbes, including:

- Nitrogen-fixing bacteria like *Azotobacter sp.*, *Agrobacterium sp.*, and *Rhizobium*.
- Phosphate-Solubilizing bacteria (PSB) that help make phosphorus available to plants.
- Beneficial fungi and actinomycetes that aid in soil health and plant growth.

Benefits of Vermiwash

- Acts as a natural fertilizer and pesticide.
- Enhances plant growth by providing essential nutrients.
- Increases microbial activity in soil, improving decomposition.
- Boosts photosynthesis and flowering in plants.
- Forms a protective layer against bacterial infections.

Principle of Vermiwash Preparation

The principle is based on earthworm activity. Earthworms create burrows, and water passing

through these burrows extracts nutrients, enzymes, and microbial secretions, forming vermiwash. (5)

Method of Preparation

- Set up a vermiwash unit using a container with a tap at the bottom.
- Layer the container with stones, sand, hay, and pre-decomposed organic waste.
- Introduce earthworms (about 1000-1500 adult or juvenile worms)
- Moisten the setup daily with water.
- Collect vermiwash after a few weeks by draining the liquid from the tap

CONCLUSION

Vermicomposting is an eco-friendly, cost-effective, and highly efficient method of converting organic waste into nutrient-rich compost and vermiwash. The process not only recycles agricultural and organic residues but also enhances soil fertility and structure, improves water retention, and supports sustainable agriculture by reducing dependency on chemical fertilizers. Through careful management of moisture, temperature, and proper selection of earthworm species like *Eisenia foetida*, farmers can produce high-quality vermicompost that supplies essential macro and micronutrients, beneficial microbes, and plant growth hormones. Additionally, vermiwash serves as an excellent liquid bio-fertilizer and natural pesticide. Together, these organic inputs boost crop yield, improve produce quality, protect the environment, and generate additional income and employment

opportunities—making vermicomposting a valuable practice for modern, sustainable farming.

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EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH, YIELD AND QUALITY OF BER (*ZIZYPHUS MAURITIANA* LAMK.) CV. BANARASI KARAKA

Monish, V. K. Tripathi* and Amit Kumar

Department of Fruit Science

Chandra Shekhar Azad University of Agriculture and Technology, Kanpur -208002, India

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

ABSTRACT

The experiment entitled effect of Integrated Nutrient Management on growth, yield and quality of Ber (*Zizyphus mauritiana* Lamk.) cv. Banarasi Karaka was conducted in Horticulture Garden, Department of Fruit Science, College of Horticulture, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, from April 2024 to March 2025. The treatment consisted of seven treatments viz. T₀-control, T₁-75% RDF + 2kg Vermicompost, T₂-75% RDF+ 4kg Vermicompost + 100g *Azotobacter*, T₃-75% RDF +2kg Vermicompost + 100g *Azotobacter*, T₄-75% RDF + 2kg Vermicompost + 100g PSB, T₅-75% RDF + 4kg Vermicompost + 100 PSB, T₆-75% RDF + 4kg Vermicompost + 50g PSB. The present investigation revealed that the combined application of 75% RDF, 4 kg of vermicompost, and 100 g of PSB (T₅) significantly enhanced all studied parameters, including plant growth, fruit yield, and quality attributes. The significantly maximum branch length (3.57 m), number of primary branches (17.37), number of secondary branches (26.57), minimum fruit drop per cent (64.23 %), maximum fruit retention (35.77%), fruit length (3.81cm), fruit width (3.67 cm), fruit volume (23.12 cc), pulp weight (20.28 g), stone weight (1.97g), yield per tree (17.50 kg), TSS (16.45 °Brix), minimum titratable acidity (0.24 %), total sugar (9.78 %), TSS: acid ratio (68.66%) and ascorbic acid (73.63mg /100g) in ber under plains of north India.

Keywords: Ber, Vermicompost, *Azotobacter*, PSB, Growth, Yield and Quality

INTRODUCTION

Ber (*Zizyphus mauritiana* Lamk.), a member of the Rhamnaceae family, is one of the most important minor fruit crops in arid and semi-arid regions, widely recognized for its resilience, adaptability, and economic value. Commonly known as Indian jujube, Chinese date or Indian plum, it is often referred as the “king of arid fruits” owing to its ability to thrive under harsh climatic conditions, low water availability and marginal soils (Usman *et al.* 2023). The fruit

is nutritionally rich, containing 14-16% sugars, approximately 150 mg of vitamin C per 100 g of pulp, and significant amounts of calcium, phosphorus, and iron (Desai, 1991). Beyond its fresh consumption, ber is processed into various value-added products such as jams, jellies, preserves, candies, chuhhara and beverages. Its roots, bark, leaves, flowers, and seeds also hold a prominent place in Ayurvedic and folk medicine, being traditionally used for ailments such as diarrhoea, ulcers, cough, asthma, and digestive disorders. This combination of nutritional, medicinal and

economic attributes makes ber a promising crop for improving livelihoods in water-limited regions.

Despite its potential, ber cultivation often suffers from poor nutrient management, leading to reduced productivity and inferior fruit quality. The over dependence on chemical fertilizers in many production systems, while providing short-term yield gains, has contributed to soil nutrient imbalances, organic matter depletion and declining soil microbial activity, whereas, Integrated Nutrient Management (INM) the strategic combination of inorganic fertilizers with organic manures and biofertilizers has emerged as an ecologically sound and economically viable approach to maintaining soil fertility and enhancing crop performance (**Biswakarma *et al.* 2025**). By improving nutrient-use efficiency, balancing the supply of macro- and micronutrients, and fostering beneficial soil microflora, INM can address both productivity and sustainability concerns.

Organic amendments, such as vermicompost, enhance soil physical properties, water-holding capacity, and aeration while enriching the soil with plant growth-promoting substances like humic acids and natural phytohormones (auxins, gibberellins, cytokinins) (**Mulatu and Bayata, 2024**). Biofertilizers, including *Azotobacter* and phosphate-solubilizing microorganisms, play a crucial role in atmospheric nitrogen fixation, phosphorus solubilization, and the synthesis of growth regulators, thereby enhancing nutrient uptake and plant vigour (**Singh *et al.* 2010; Ali *et al.* 2023; Khairi and Joody, 2025**). While the benefits of these inputs have been demonstrated in several fruit crops, systematic studies on their combined application in ber, particularly the high-yielding cultivar Banarasi Karaka, are scarce.

Although INM benefits have been

demonstrated in several fruit crops, systematic research on its role in improving growth, yield and quality of ber, particularly the high-yielding cultivar Banarasi Karaka, remains limited. Addressing this gap, the present study evaluates the effect of integrated nutrient management practices on the growth, yield and quality attributes of ber cv. Banarasi Karaka aims to develop a balanced and sustainable nutrient strategy for enhanced productivity and fruit quality in the plains of northern India.

MATERIALS AND METHODS

The present investigation was conducted at Horticulture Garden, Department of Fruit Science, College of Horticulture, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.). Geographically, Kanpur district falls in the sub-tropical zone and is situated between 25.26° and 26.58° North latitude and 79.31° and 80.34° East longitude. It is located at an elevation of 135 meters above mean sea level. The mean annual rainfall of the district is 108.35 cm (2025). The climate is subtropical, characterized by a hot, dry summer and severe cold winters. The experiment started in the third fortnight of April. The experiment consisted of 7 treatments, including fertilizer and vermicompost, as well as biofertilizers such as *Azotobacter* and PSB. The experiment was laid out in a Randomized Block design. The treatment consisted of seven treatments *viz.*, T₀-control, T₁-75% RDF + 2kg Vermicompost, T₂- 75% RDF+ 4kg Vermicompost + 100g *Azotobacter*, T₃-75% RDF +2kg Vermicompost + 100g *Azotobacter*, T₄-75% RDF + 2kg Vermicompost + 100g PSB, T₅-75% RDF + 4kg Vermicompost + 100 PSB, T₆-75% RDF + 4kg Vermicompost + 50g PSB. Vermicompost @ 2 and 4kg/plant, along with NPK and bio-fertilizers, was applied around each tree in the third week of July. The bio-fertilizers, *viz.*, *Azotobacter* and PSB

(100g/tree each), were applied in the rhizosphere zone of the tree at a depth of 15cm, leaving 50cm from the main trunk. The RDF of NPK (750:350:750g/tree) fertilizers were applied in the form of Urea, DAP and MOP, respectively. The observation on Growth parameters *viz.*, branch length (m), number of primary and secondary branches on selected, fruits drop and fruit retention, yield parameters *viz.* fruit weight (g), fruit diameter (cm), fruit volume (cc), pulp weight (g), stone weight (g) and yield per tree (kg) and quality parameters *viz.*, TSS ($^{\circ}$ Brix), titratable acidity (%), TSS: acid ratio, ascorbic acid content. Sample fruits of each plant were crushed to form a homogenized sample and then the juice was extracted through a muslin cloth. The extract was used to determine TSS in $^{\circ}$ Brix with the aid of a hand refractometer. A few drops of juice were placed on the surface of the prism. The hinged part was placed back. The refractometer was then placed against the sun, and the reading was noted by revolving the eyepiece at room temperature. Total sugars were estimated as suggested by **Ranganna (1986)**. Titratable acidity was estimated using the standard acid-alkali titration method, while ascorbic acid content was determined according to the procedure as detailed in **(AOAC, 1984)**.

The data were analyzed according to the method described by **Panse and Sukhatme (1985)**. To compare one treatment with another and to determine the effectiveness of different treatments, all the data were subjected to statistical analysis. Significant responses at a 5.0 per cent level were computed, wherever necessary. Critical differences (C.D.) were worked out to compare the effects of various treatments.

RESULTS AND DISCUSSION

Growth parameter

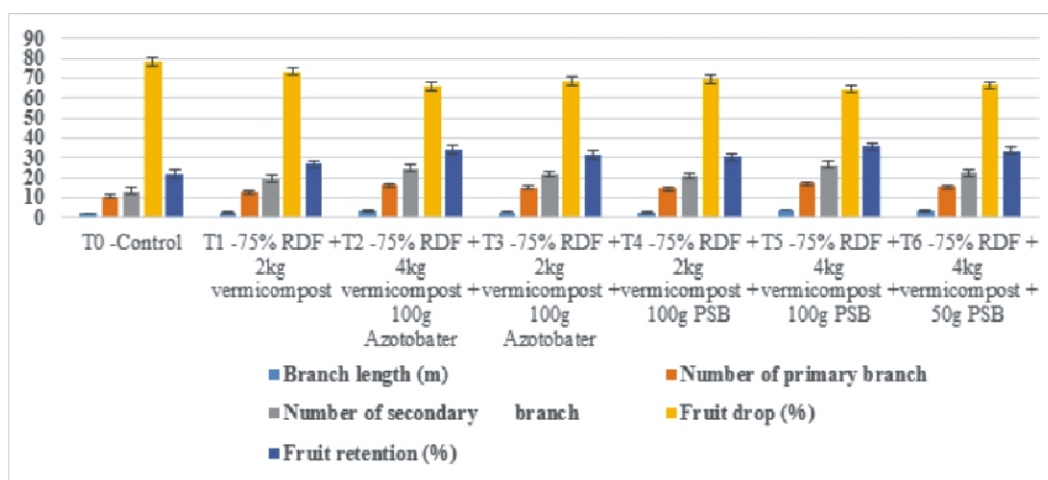
Integrated nutrient management

treatments significantly influenced the growth parameters of the plants. During present experimental findings (Table 1 and Fig. 1) the maximum increase in branch length (3.57 m), number of primary branch (17.37), number of secondary (26.57), minimum fruit drop (64.23) and fruit retention (35.77) were recorded in the treatment T_5 (75 % RDF + 4kg Vermicompost + 100g PSB), whereas, the minimum branch length (2.10 m), number of primary branch (10.57), number of secondary branch (13.22) and fruit retention (21.75) were recorded in plant under kept control. The plants under control resulted in a maximum fruit drop percentage (78.25%).

The optimum dose of nutrient combinations (NPK) accelerates the metabolic activities of the plant by increasing meristematic activities, which in turn enhances vegetative growth, increases photosynthates, and ultimately leads to increased flowering, maximum fruit setting percentage, and maximum fruit retention percentage. The improved vegetative growth due to organics may have been reflected in increased flower production and resulted in a higher percentage of fruit set. The increased fruit set due to vermicompost could be attributed to the presence of B-group vitamins, plant hormones, and chemical exudates released during biological activity promoted by the vermicompost in the soil. Vermicompost has a very high porosity, aeration, drainage, and water-holding capacity, with a vast surface area, providing strong absorbability and retention of nutrients for a longer period, thereby increasing fruit setting and fruit retention percentage. The present findings are in accordance with the results reported by **Singh et al. (2010)** in ber, **Tripathi et al. (2016)** in strawberry, **Singh and Tripathi (2020)** in papaya, and **Katiyar et al. (2012)** in ber, as well as by **Goswami et al. (2012)** in guava.

Table 1. Effect of integrated nutrient management on the growth of Ber (*Zizyphus mauritiana* Lamk.) cv. Banarasi Karaka.

Treatments	Branch length (m)	Number of primary branches	Number of secondary branches	Fruit drop (%)	Fruit retention (%)
T ₀ -Control	2.10	10.57	13.22	78.25	21.75
T ₁ -75% RDF + 2kg vermicompost	2.34	12.81	19.54	73.32	26.68
T ₂ -75% RDF + 4kg vermicompost + 100g Azotobater	3.40	16.26	24.72	65.87	34.13
T ₃ -75% RDF + 2kg vermicompost + 100g Azotobater	2.85	15.01	21.88	68.50	31.50
T ₄ -75% RDF + 2kg vermicompost + 100g PSB	2.52	14.67	20.91	69.46	30.54
T ₅ -75% RDF + 4kg vermicompost + 100g PSB	3.57	17.37	26.57	64.23	35.77
T ₆ -75% RDF + 4kg vermicompost + 50g PSB	3.25	15.57	22.45	66.53	33.47
S.E m (±)	0.041	0.35	0.49	1.53	1.03
C.D at 5% level	0.089	0.77	1.07	3.364	2.26

**Fig. 1** Effect of integrated nutrient management on the growth of Ber (*Zizyphus mauritiana* Lamk.) cv. Banarasi Karaka

Fruit and yield parameters

In the present investigation (Table 2 and Fig. 2), fruit length, fruit width, weight, volume, pulp weight and stone weight were significantly influenced by different integrated doses. The highest fruit length (3.81cm) and width (3.67cm) were observed with the application of T₅-75% RDF + 4kg Vermicompost + 100g PSB. The lowest value of fruit length (2.85 cm) and width (2.08 cm) was observed in the plant produced for the control. Similar findings were reported by **Tripathi *et al.* (2014a)** in strawberry and **Tripathi (2017)** in banana. The highest average fruit weight (22.25g), volume (23.12cc), pulp weight (20.28g) and stone weight (1.90g) was found in the plants treated with the application of 75% RDF + 4kg Vermicompost + 100g PSB (T₅) and lowest in control average fruit weight (13.32g), fruit volume (14.15cc), pulp weight (12.22g) and stone weight (1.10g), respectively. The maximum gain in fruit weight and volume under T₅ was due to the greater mobility of metabolites into the developing fruits, which acted as a strong metabolic sink compared to the treatments involving higher doses of NPK, Vermicompost, and bio-fertilizers. Similar results were also obtained by **Gupta and Tripathi (2012)** in strawberry and **Singh *et al.* (2010)** in ber.

The maximum fruit yield (17.50 kg/tree) was recorded in the plants which were treated with 75% RDF+4 kg vermicompost + 100g PSB (T₅), closely followed by the application of 75% RDF + 4kg vermicompost + 100g *Azotobacter* (T₂), which gave a yield of 16.29kg/tree. The yield was better in the treatment combination of NPK, Vermicompost, and bio-fertilizers, which may be due to the better growth and development of the plants under these treatments compared to the control. The present findings are in conformity with the earlier work of **Gupta and Tripathi (2012)** on strawberry, and **Mishra and Tripathi (2011)** also found higher yields with the combined application of 6kg/ha each of *Azotobacter* and PSB in strawberry cv. Chandler.

Table 2. Effect of integrated nutrient management on fruit and yield of Ber (*Zizyphus mauritiana* Lamk.) cv. Banarasi Karaka

Treatment	Fruit length (cm)	Fruit width (cm)	Fruit volume (cc)	Average fruit weight (g)	Pulp weight (g)	Stone weight(g)
T ₀ -Control	2.85	2.08	14.15	13.32	12.22	1.10
T ₁ -75% RDF + 2kg vermicompost	3.34	2.91	18.64	18.56	17.11	1.45
T ₂ -75% RDF + 4kg vermicompost + 100g <i>Azotobacter</i>	3.72	3.51	22.35	21.63	19.85	1.78
T ₃ -75% RDF + 2kg vermicompost + 100g <i>Azotobacter</i>	3.56	3.36	20.33	20.21	18.74	1.54
T ₄ -75% RDF + 2kg vermicompost + 100g PSB	3.44	3.32	19.32	18.94	17.40	1.47
T ₅ -75% RDF + 4kg vermicompost + 100g PSB	3.81	3.67	23.12	22.25	20.28	1.970
T ₆ -75% RDF + 4kg vermicompost + 50g PSB	3.66	3.44	21.89	20.890	19.22	1.673
S.E m (±)	0.08	0.06	0.47	0.34	0.35	0.03
C.D at 5% level	0.17	0.14	1.04	0.76	0.78	0.06

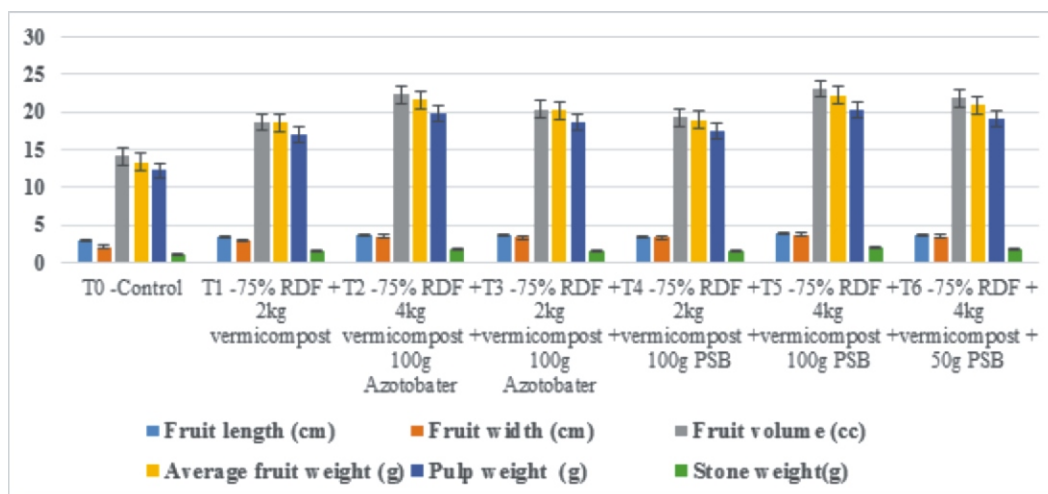


Fig. 2. Effect of integrated nutrient management on fruit and yield of Ber (*Zizyphus mauritiana* Lamk.) cv. Banarasi Karaka

Quality parameter

The chemical parameters of fruit *viz.*, total soluble solids, titratable acidity, TSS: acid ratio, total sugars and ascorbic acid as influenced by different treatments were studied (Table 3 and Fig. 3) and highest TSS (16.45 °Brix), TSS: acid ratio (68.66%) and total sugars (9.78%) were observed in plant produced for the plants treated with the application of 75% NPK + 4kg

Vermicompost +100g *Azotobacter* + 100g PSB (T₅). The lowest amounts of TSS (11.00 °Brix), TSS: acid ratio (32.34%), and total sugars (7.24%) were recorded in the control. *The application of Azotobacter and PSB may be attributed to the rapid metabolic transformation of starch and pectin into soluble compounds, as well as the quick translocation of sugars from leaves to developing fruits.* These results are in agreement with the findings of **Athani *et al.* (2009)** in guava, **Mishra and Tripathi (2011)** in strawberry, **Gupta and Tripathi (2012)** in strawberry, **Singh *et al.* (2010)** in ber. The minimum titratable acidity (0.24%) was observed in (T₅) and the highest (0.34%) in control (T₁). Similar results were also reported by **Nayyer *et al.* (2014)** and **Tripathi (2017)** in banana, **Tripathi *et al.* (2016)** in strawberry. The observation on ascorbic acid content revealed that treatment with 75% RDF + 4 kg Vermicompost + 100g PSB (T₅) yielded the highest ascorbic acid content (73.63 mg/100g of pulp). At the same time, the control had the lowest (63.34mg/100g of pulp). The possible reasons for the increased ascorbic acid may be due to the conversion of soluble sugars into ascorbic acid. Similar findings have been reported by **Tripathi *et al.* (2014b)** in banana and **Athani *et al.* (2009)** in guava.

Table 3. Effect of integrated nutrient management on the quality of Ber (*Zizyphus mauritiana* Lamk.) cv. Banarasi Karaka

Treatment	TSS (°Brix)	Titratable acidity (%)	TSS: acid ratio	Total sugar (%)	Ascorbic acid (mg/100g)
T ₀ -Control	11.00	0.34	32.34	7.24	63.34
T ₁ -75% RDF + 2kg vermicompost	12.08	0.31	38.96	8.25	64.56
T ₂ -75% RDF + 4kg vermicompost + 100g Azotobacter	14.76	0.26	54.69	9.07	71.57
T ₃ -75% RDF + 2kg vermicompost + 100g Azotobacter	14.09	0.29	46.97	8.68	68.34
T ₄ -75% RDF + 2kg vermicompost + 100g PSB	13.54	0.30	46.72	8.02	67.23
T ₅ -75% RDF + 4kg vermicompost + 100g PSB	16.45	0.24	68.66	9.78	73.63
T ₆ -75% RDF + 4kg vermicompost + 50g PSB	14.15	0.27	54.51	8.92	69.45
S.E m (±)	0.30	0.006	1.92	0.17	1.34
C.D at 5% level	0.67	0.014	4.24	0.41	2.94

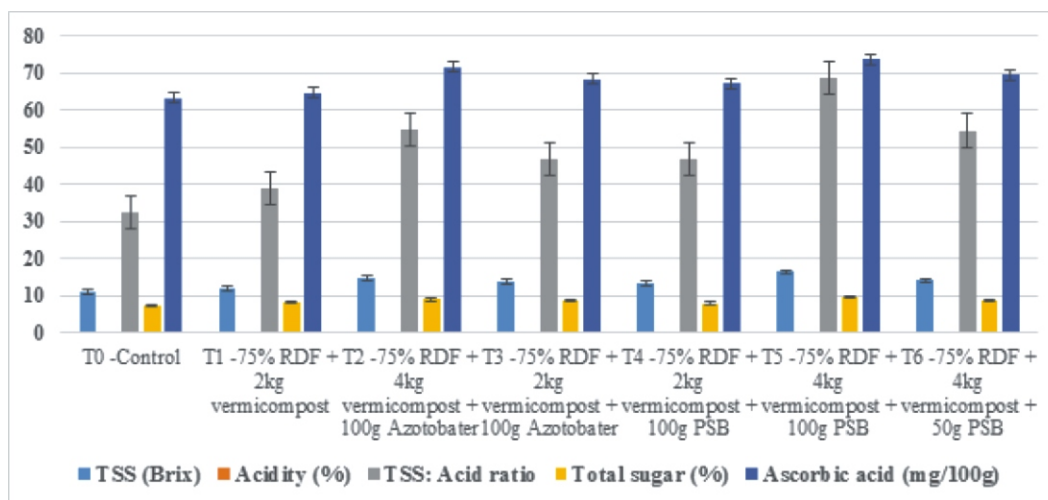


Fig. 3 Effect of integrated nutrient management on the quality of Ber (*Zizyphus mauritiana* Lamk.) cv. Banarasi Karaka

CONCLUSIONS

The present investigation revealed that the combined application of 75% RDF, 4 kg of vermicompost, and 100 g of PSB (T₅) significantly enhanced all parameters, including plant growth, fruit yield, and quality attributes. Especially, T₅ treatment resulted in maximum branch length, number of branches, number of secondary branches, fruit retention, fruit length, fruit diameter, fruit volume, average fruit weight, stone weight, pulp weight, yield per tree, total soluble solids, sugars content, TSS: acid ratio and ascorbic acid content with reducing fruit drop and titratable acidity, thus offering a superior nutrient management strategy. These findings highlight the potential of integrating organics and biofertilizers with reduced chemical inputs for sustainable and eco-friendly ber cultivation.

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IMPACT OF DIFFERENT SOILLESS MEDIA ON VEGETATIVE GROWTH OF CUCUMBER (*CUCUMIS SATIVUS* L.) UNDER POLYHOUSE CONDITIONS

Akshat Gupta¹, Sarvesh Kumar Lodhi¹, Manoj Kumar Singh¹,
Satya Prakash¹, Nikita Yadav¹, Gajresh Kumar¹, Shailendra Kumar Yadav²

¹Department of Vegetable Science, ²Department of Agricultural Extension Education
Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut U.P. 251001

*Corresponding Author E-mail–guptakky234452@gmail.com

ABSTRACT

This study evaluates the effect of different soilless growing media on physiological properties of media and growth parameters of cucumber (*Cucumis sativus* L.) under Polyhouse conditions during 2024 at Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, U.P. The experiment was carried out in completely randomized design (CRD) with 3 replications comprising 10 treatment combinations. The media tested include cocopeat, biochar, rice husk, and their various combinations. Physiological parameters assessed were water holding capacity (WHC), pH, and bulk density, while plant growth was evaluated based on vine length, number of leaves, days to first female flower appearance, and root and shoot fresh weight. The results showed that media combination significantly influenced all physiological and growth parameters. Among different media combination T₈ with 12.5% cocopeat+12.5% Biochar+75% rice husk recorded the highest vine length (273.91 cm), leaf number (54.00), and root-shoot biomass(109.50g) as well as the earliest female flower appearance (25.17 DAS). Cocopeat alone (T₁) exhibited the highest water holding capacity (64.49%) but had limitations in aeration indicated by low bulk density values (0.090 Mg/m³). (T₂) Biochar (100%) treatments recorded higher pH values (8.77). The study concludes that balanced media formulations enhance root environment and plant physiological responses conducive to vigorous growth in protected cucumber cultivation.

Keywords: Growing media, Cocopeat, Biochar, Ricehusk, Cucumber, Soilless

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is an important vegetable crop belongs to Cucurbitaceae family widely grown under protected cultivation due to its high market demand and sensitivity to environmental fluctuations. The possible progenitor of cucumber is *Cucumis hardwickii* Royle, a wild species found in the foothill of the Himalayas.

Besides *Cucumis sativus* L. the genus *Cucumis* comprises about 30 different species. Cucumber is the fourth most important vegetable crop after tomato, cabbage and onion. It is used as a Salad, Sandwich, Rayta, Pickles and Pizza preparation etc. It is also useful for people suffering from kidney problems, constipation, jaundice and indigestion. Oil extraction from seeds is

considered good for the brain and body. (6). Nutritionally, cucumbers are very high in water content and low in calories and but provide essential vitamins and minerals, including Vitamin K, Vitamin C, potassium, magnesium and manganese along with beneficial antioxidants like cucurbitacin, flavonoids and tannins. These components contribute to potential health benefits such as improved digestion, blood sugar regulation, anti-inflammatory effects and skin health.

The off season production of cucumber is possible by using suitable parthenocarpic varieties with the suitable microclimate under protected structure (3). Protected cultivation is a technique of growing horticultural crops under a protected structure to protect them from pest and weather simultaneously increasing production of quality products. The *insitu* cultivation of plants without soil is defined as “*soilless culture*” (4). Media physical and chemical properties, including water holding capacity (WHC), pH, and bulk density, critically affect root health, nutrient availability, and ultimately plant growth. Effective media must balance moisture retention with aeration and maintain an optimal pH to support nutrient uptake and root respiration (1; 4).

This study investigates the impact of different soilless media and their combinations on the physiological properties of the media and the growth attributes of cucumber under polyhouse conditions. Key growth indicators include vine length, leaf number, timing of female flower appearance, and root-shoot fresh weight, which collectively reflect plant vigour and potential productivity. The findings aim to inform the choice of suitable media for optimizing cucumber cultivation in protected environments.

MATERIAL AND METHODS

Experimental site and location

The experiment was carried out at the Sardar Vallabhbhai Patel University of Agriculture and Technology in Meerut [UP] in the College of Horticulture and College of Post-Harvest Technology and Food Processing. The institution is located on the Meerut- Roorkee route, approximately 11 kilometres from the city of Meerut. Meerut is located at a geographical position of 29.01° North Latitude and 77.75° East Longitude with an elevation of 297 meters above sea level.

Experimental Design

A completely randomized design (CRD) was adopted with ten treatments comprising pure media and their blends at specified volumetric ratios. Treatments include 100% cocopeat (CP) (T₁), 100% Biochar (BC) (T₂), 100% ricehusk (RH) (T₃), CP (75%) + BC (12.5%) + RH (12.5%) (T₄), CP (50%) + BC (25%) + RH (25%) (T₅), CP (12.5%) + BC (75%) + RH (12.5%) (T₆), CP (25%) + BC (50%) + RH (25%) (T₇), CP (12.5%) + BC (12.5%) + RH (75%) (T₈), CP (25%) + BC (25%) + RH (50%) (T₉) and CP (33.33%) + BC (33.33%) + RH (33.33%) (T₁₀). The experiment was conducted at the polyhouse of the Department of Vegetable Science, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, from July to October 2024.

Agronomic practices

Three seeds were sown per growbag at a depth of 2cm. N: P: K 19:19:19 is given in 2-5 g/L depending on plant growth stage twice weekly. Micronutrient supplied 2g/L once a week through drenching. Temperature of greenhouse maintained at 24-27.5°C and relative humidity at 72-78%.

Data collection

Data were collected for water holding capacity, pH and bulk density before sowing and for vine length and number of leaves at 30DAS, 60DAS and at harvest. Root and shoot fresh weight recorded after final harvest. Data were collected on the reproductive parts when flowers appeared. Vine length was measured using a ruler calibrated in cm from the base of the plant to the tip of the plant. Data on the number of leaves was obtained by visually counting the number of leaves on the plant.

Media Preparation

Media was prepared with different combinations of cocopeat, biochar and ricehusk on volume basis as per the treatments and filled into the grow bags. The grow bags were filled with media and arranged at 2x2 feet spacing. Variety used in the experiment is 'Dacnis' improved variety of parthenocarpic gynoecious cucumber from Syngenta India. Seeds were directly sown in media. Observations recorded in growth parameters were Vine length (30 DAS, 60 DAS and at harvest), Number of leaves (30 DAS, 60 DAS and at harvest), days to first female flower appearance and root-shoot biomass and in media parameters were water holding capacity, bulk density and pH values were measured as per the standard procedures.

RESULTS

Physiological Properties of Media

Water holding capacity varied significantly among treatments, with pure cocopeat (T₁) showing the highest WHC at 64.49%, followed by combinations with higher cocopeat proportions (T₄: 55.24%, T₅: 46.00%). Media composed solely of rice husk (T₃) had the lowest WHC (23.00%) (Table 1). Bulk density was lowest in T₁ (0.090 Mg/m³), indicating

high porosity but potential root support issues, and highest in rice husk media (0.323 Mg/m³), reflecting increased compaction (Table 1). Media pH ranged from 6.08 in T₁ to 8.77 in biochar-only media T₂, with blended media showing intermediate pH values supportive of nutrient availability and root health (Table 1).

Growth Parameters of Cucumber

Vine length increased significantly with media combinations containing higher proportions of rice husk and biochar. The longest vines at harvest were observed in T₈ (273.91 cm), followed by T₉ (254.16 cm) and T₇ (259.77 cm), whereas T₁ recorded the shortest vine length (189.43 cm) (Table 2). Similarly, leaf count was highest in T₈ (54.00) leaves per plant at harvest, followed by T₉ (52.00) and T₇ (51.00), while the lowest was in T₁ (40.83) (Table 2).

The earliest first female flower appearance occurred in T₈ at 25.17 days, indicating accelerated reproductive development, while T₁ delayed flowering until 41.67 days (Table 2). Root and shoot fresh weight was highest in T₈ (109.50 g), followed by T₇ (104.80 g) and T₉ (101.74 g), underscoring superior plant vigour in optimized media mixes (Table 2).

Table 1: Effect of different growing media combinations on physiological properties of media

Treatments	Water holding capacity (%)	pH	Bulk density (Mg/m ³)
T ₁	64.49	6.08	0.090
T ₂	32.50	8.77	0.163
T ₃	23.00	6.45	0.323
T ₄	55.24	6.42	0.130
T ₅	46.00	6.87	0.167
T ₆	34.94	8.27	0.173
T ₇	37.87	7.38	0.187
T ₈	29.31	6.66	0.273
T ₉	35.62	6.95	0.223
T ₁₀	39.83	7.13	0.200
SEm	0.63	0.10	0.004
CD at 1%	2.53	0.40	0.015
CV (%)	2.73	2.42	3.411

Table 2: Effect of different growing media combinations on growth parameters of plant in soilless cultivation

Treatments	Vine Length (cm) means			Number of leaves means			First female flower appearance (DAS) means	Root and shoot fresh weight (g) mean
	30 DAS	60 DAS	At Harvest	30 DAS	60 DAS	At Harvest		
T ₁	38.36	103.46	189.43	8.67	20.67	40.83	41.67	75.50
T ₂	42.67	142.38	222.16	10.67	24.66	46.17	34.17	88.10
T ₃	42.24	141.02	212.62	8.50	21.67	43.67	36.83	86.85
T ₄	38.57	115.39	198.83	9.00	22.33	42.67	31.17	78.98
T ₅	40.21	119.58	196.38	8.84	21.83	41.50	39.83	78.67
T ₆	40.36	137.58	206.80	9.33	24.17	44.00	38.50	83.72
T ₇	44.30	194.91	259.77	9.50	30.16	51.00	26.83	104.80
T ₈	48.44	214.72	273.91	12.83	33.33	54.00	25.17	109.50
T ₉	44.52	206.74	254.16	11.17	32.00	52.00	31.00	101.74
T ₁₀	43.15	150.99	231.79	10.50	25.33	48.67	33.33	102.33
SEm	1.25	5.37	8.09	0.38	1.12	2.30	1.42	2.91
CD at 1%	5.05	21.63	32.57	1.54	4.50	9.24	5.71	11.73
CV (%)	5.14	6.09	6.24	6.68	7.56	8.56	7.26	5.54

CONCLUSION

The study confirms that soilless media consisting of balanced combinations of cocopeat, biochar, and rice husk provide the most favourable physical and chemical environment for cucumber cultivation under polyhouse conditions. Cocopeat alone supplies high moisture but limits aeration, while biochar and rice husk improve structural characteristics and pH balance. These integrative media foster enhanced vine growth, leaf development, early flowering, and greater root-shoot biomass compared to single-media substrates. Optimizing media formulations is essential for achieving vigorous cucumber growth in protected cultivation systems.

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“STUDY ON GENETIC VARIABILITY, HERITABILITY, CHARACTER ASSOCIATION AND GENETIC DIVERGENCE IN RIDGE GOURD [*LUFFA ACUTANGULA* (ROXB.) L.]”

Riya Kushwaha, Hariom Katiyar*, Bijendra Singh and Esha Kanojia

Department of Vegetable Science, SVPUAT, Meerut 250110, (U.P.), India

*Corresponding Author E-mail–mauryadisha786@gmail.com, hariom.ext@svpuat.edu.in

ABSTRACT

The Horticulture Research Centre, College of Horticulture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.) conducted an experiment on genetic variability, heritability, and genetic divergence in twenty genotypes of ridge gourd during the 2024 kharif season. Fifteen characters that contributed to yield and yield were observed. The current investigation's findings showed that genotypes IC-429970 (201.70 q/ha) and IC-355961 (196.40 q/ha) were superior in terms of fruit production per hectare (q) based on mean performance. Analysis of variance revealed that all genotypes differed significantly, indicating that there is a high amount of genetic diversity. The greatest estimates of genotypic and phenotypic coefficients of variation were found from node to first male flower appearance (25.43% and 25.75%). The heritability estimate was found to be high (>60) for node to first male flower appearance (97.55%, 51.75), demonstrating the dominance of additive gene action. Genetic divergence study separated the twenty genotypes into four groupings. The most inter-cluster distance was found between Cluster III and Cluster I (5.738), followed by Cluster II and Cluster IV (5.114). Cluster I had the highest average fruit output per hectare (187.76 q/ha), while Cluster III had a modest yield but greater blooming trait values. As a result, hybridization between genotypes from Clusters I and III may produce superior segregants that combine early maturity with higher output. In the current study, crop duration (11.04), days to germination (10.58), days to first female flower appearance (9.27), days to first male flower appearance (8.50), and vine length (8.37) all contributed significantly to the expression of genetic divergence.

Keywords- Ridge gourd, genetic variability, heritability, genetic divergence

INTRODUCTION

Ridge gourd [*Luffa acutangula* (L.) Roxb.], also known as Kalitori, angled gourd, ribbed gourd or Chinese okra, is an important cucurbit belonging to the family Cucurbitaceae with a chromosome number of $2n = 26$. It is cultivated widely during spring, summer and rainy

seasons, both for its immature tender fruits consumed as vegetable and mature fibrous fruits used as natural cleaning agents and industrial raw material. India is recognized as a primary center of origin and diversity for *Luffa* species, with several landraces grown across agro-ecological zones. The crop is mainly cultivated in Karnataka, Andhra Pradesh,

Tamil Nadu, Uttar Pradesh, Madhya Pradesh and Maharashtra. During 2018–19, India produced 185.88 million tonnes of vegetables from 10.1 million hectares, of which ridge gourd accounted for 10.03 thousand hectares with 3.16 million tonnes production (NHB, 2019–20).

Nutritionally, ridge gourd fruits are rich in moisture (95.2 g), protein (0.5%), carbohydrates (3%), calcium (18 mg), phosphorus (26 mg), iron (0.5 mg), carotene (33 µg) and vitamin C (5 mg) per 100 g of edible portion, making it valuable in daily diets, especially for lifestyle disorders like diabetes and hypertension due to its low calories and high fiber. In addition to food use, its mature fruits provide loofah fiber for mats, slippers, insulators and eco-friendly packaging. Medicinally, extracts possess immunomodulatory, antioxidant, larvicidal and insecticidal properties, while seed oil has potential in soap and biodiesel production.

Being a monoecious, cross-pollinated crop, ridge gourd exhibits considerable variation in floral and fruit traits. However, limited efforts have been made in its systematic genetic improvement. The success of crop improvement depends on the extent of genetic variability, heritability and genetic divergence among available germplasm. Assessment of variability and divergence not only helps in understanding the nature of traits influencing yield but also in identifying diverse parents for hybridization to exploit heterosis and develop superior cultivars.

MATERIALS AND METHODS

The field investigation was carried out during the kharif season of 2024 at the Horticulture Research Centre, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.). A total of twenty diverse ridge gourd genotypes were evaluated in a Randomized Block Design (RBD) with three replications. Each genotype was planted

at a spacing of 3.0 m × 1.5 m, and all recommended crop management and plant protection practices were adopted to ensure a healthy crop stand. Data were recorded on fifteen morphological and yield-related characters, including days to germination, days to first male flower, days to first female flower, days to first fruit set, days to crop finish, vine length, number of branches per vine, node to first male flower anthesis, node to first female flower anthesis, number of fruits per plant, fruit weight, fruit length, fruit diameter, fruit yield per plant, and fruit yield per hectare.

The collected data were subjected to analysis of variance (ANOVA) following the procedure suggested by Panse and Sukhatme (1967). Estimates of genetic variability parameters such as genotypic and phenotypic coefficients of variation (GCV and PCV), heritability (broad sense), and genetic advance were calculated according to the method outlined by Burton (1952). Genotypic and phenotypic correlation coefficients were worked out as per the method of (2), while path coefficient analysis was carried out following (5). The extent of genetic divergence among genotypes was assessed using Mahalanobis D² statistics as described by (13).

RESULTS AND DISCUSSION

The analysis of variance (ANOVA) revealed significant differences among the 20 ridge gourd genotypes for all the 15 characters studied. The differences were significant at both the 0.1% and 5% probability levels, indicating the existence of considerable genetic variability among the genotypes. Similar findings regarding significant variance among genotypes have also been reported by (1), (3), (8), (12), (14).

Among the genotypes, IC-429970 recorded the highest mean performance for fruit yield per hectare (201.70 q), followed by IC-355961 (196.40 q), while the lowest yield was observed in IC-393298 (104.40 q).

The estimates of genotypic and phenotypic coefficients of variation (GCV and PCV) showed the highest values for node at which first male flower appeared (25.43% and 25.75%), suggesting the presence of a high degree of variability as well as the influence of environmental factors on the expression of this trait. These findings are in line with the results reported by (24).

The heritability estimates were found to be high (>60%) for several traits, including node to first male flower anthesis, node to first female flower anthesis, fruit yield per plant, fruit yield per hectare, number of branches per vine, fruit weight, number of fruits per plant, vine length, fruit diameter, fruit length, days to first male flower appearance, days to germination, days to first fruit set, and days to first female flower appearance.

The estimates of genetic advance (GA) as a percentage of mean were categorized as low (0–10%), moderate (10–20%), and high (>20%) as suggested by (7) and Falconer and Mackay (1996). High genetic advance as a percentage of mean was recorded for node to first male flower anthesis, node to first female flower anthesis, fruit yield per plant, fruit yield per hectare, number of branches per vine, fruit weight, number of fruits per plant, vine length, and fruit diameter.

The correlation coefficient analysis indicated that fruit yield per hectare had a significant and positive association with fruit yield per plant, fruit weight, vine length, number of fruits per plant, and number of branches per vine. In contrast, a significant negative association was observed with node to first male flower anthesis, days to germination, days to first female flower appearance, days to first male flower appearance, days to first fruit set, and crop duration.

The genotypic path coefficient analysis revealed that the highest direct positive effects on

fruit yield per hectare were contributed by node to first male flower anthesis, fruit weight, node to first female flower anthesis, number of fruits per plant, vine length, days to first male flower appearance, fruit length, and number of branches per vine. Negative direct effects were recorded for days to germination, fruit yield per plant, fruit diameter, crop duration, days to first female flower appearance, and days to first fruit set.

At the phenotypic level, the maximum positive direct effects on fruit yield per hectare were exhibited by fruit yield per plant, vine length, number of fruits per plant, node to first female flower anthesis, fruit length, days to first male flower appearance, days to germination, fruit weight, and days to first fruit set. On the other hand, negative direct effects were recorded for fruit diameter, node to first male flower anthesis, number of branches per vine, crop duration, and days to first female flower appearance.

The genetic divergence analysis (D^2 statistics) grouped the 20 genotypes into four distinct clusters. Among them, Cluster I was the largest, comprising seven genotypes, followed by Cluster III (six genotypes), Cluster II (five genotypes), and Cluster IV (two genotypes).

The maximum inter-cluster distance was recorded between Cluster III and Cluster I (5.738), followed by Cluster III and Cluster II (5.124), Cluster II and Cluster IV (5.114), Cluster I and Cluster II (5.005), and Cluster I and Cluster IV (4.425). The least inter-cluster distance was observed between Cluster III and Cluster IV (3.435).

The highest contribution to the manifestation of genetic divergence was made by crop duration, days to germination, days to first female flower appearance, days to first male flower appearance, and vine length, indicating that selection based on these traits would be highly rewarding for genetic improvement in ridge gourd.

Table 1 : Analysis of variance for 15 characters in 20 genotypes of ridge gourd

Source of variation	Replication	Treatment	Error	Total
Degree of freedom	2	19	38	59
Days to germination	0.06	1.12**	0.07	0.41
Days to first male flower appearance	7.59	48.30**	2.87	17.66
Days to first female flower appearance	2.91	48.31**	4.17	18.34
Days to first fruit set	0.07	47.49**	3.79	17.74
Duration of crop	1.19	47.48**	14.66	24.77
Vine length	379.33	22733.68**	872.09	7895.56
lparNumber of branches per vine	0.07	12.32**	0.20	4.10
Node at which first male flower anthesis	0.01	9.01**	0.07	2.95
Node at which first female flower anthesis	0.26	20.48**	0.18	6.72
Number of fruits per plant	1.07	99.05	2.57	33.59
Fruit weight (cm)	34.09	1878.92	32.90	627.42
Fruit length (cm)	1.55	10.64	0.61	3.87
Fruit diameter (cm)	0.06	0.74	0.03	0.26
Fruit yield per plant (kg)	0.39	6.12	0.07	2.03
Fruit yield per hectare (quintal)	22.62	3018.86	43.9920	1001.21

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

Table 2 : Estimation of genetic variability, GCV, PCV, heritability, genetic advance and genetic advance as per cent of mean for 15 characters in ridge gourd genotypes

Character	var (g)	var (p)	GA	Heritability (%)	GA% mean	GCV (%)	PCV (%)	% CONT
Days to germination	0.35	0.42	1.11	83.20	17.29	9.20	10.09	10.58
Days to first male flower appearance	15.14	18.01	7.35	84.07	17.06	9.03	9.85	8.50
Days to first female flower appearance	14.71	18.88	6.97	77.91	14.16	7.79	8.82	9.27
Days to first fruit set	14.57	18.36	7.00	79.34	12.85	7.00	7.86	8.11
Duration of crop	10.94	25.60	4.45	42.72	3.89	2.89	4.42	11.04
Vine length	7287.20	8159.29	166.19	89.31	23.48	12.06	12.76	8.37
Number of branches per vine	4.04	4.24	4.04	95.29	35.60	17.70	18.13	7.06
Node at which first male flower anthesis	2.98	3.05	3.51	97.55	51.75	25.43	25.75	5.81
Node at which first female flower anthesis	6.77	6.95	5.29	97.35	48.43	23.82	24.15	5.40
Number of fruits per plant	32.16	34.73	11.24	92.60	26.29	13.26	13.78	6.89
Fruit weight (gm)	615.34	648.24	49.79	94.93	30.95	15.42	15.83	6.21
Fruit length (cm)	3.34	3.95	3.46	84.58	16.07	8.48	9.22	2.60
Fruit diameter (cm)	0.24	0.26	0.94	89.17	21.61	11.11	11.76	5.26
Fruit yield per plant (kg)	2.02	2.08	2.88	96.87	41.93	20.68	21.01	3.14
Fruit yield per hectare (quintal)	991.65	1035.55	63.48	95.76	41.60	20.64	21.09	1.75

Table 4 : Cluster mean values for seventeen growth and yield characters of Ridge Gourd

Characters	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Days to germination	6.06	6.73	6.54	6.66
Days to first male flower appearance	39.44	42.04	47.66	44.79
Days to first female flower appearance	45.71	48.02	53.96	50.49
Days to first fruit set	50.96	53.40	59.11	55.83
Duration of crop	110.96	113.40	119.11	115.83
Vine length (cm)	743.86	579.20	752.17	768.50
Number of branches per vine	11.60	9.02	12.32	13.45
Node at which first male flower anthesis	5.43	6.18	8.68	7.39
Node at which first female flower anthesis	9.49	9.40	13.97	10.56
Number of fruits per plant	44.95	33.74	45.92	48.13
Fruit weight (gm)	188.34	154.69	141.83	137.28
Fruit length (cm)	20.93	22.25	22.49	19.24
Fruit diameter (cm)	4.24	4.58	4.59	3.68
Fruit yield per plant (kg)	8.47	5.21	6.46	6.66
Fruit yield per hectare (quintal)	187.76	122.22	144.72	147.80

Table 4 : Intra and inter cluster distance (D 2) of Ridge Gourd

Clusters	I	II	III	IV
I	2.139			
II	5.005	2.733		
III	5.738	5.124	2.086	
IV	4.425	5.114	3.435	1.287

CONCLUSION

Based on the mean performance of the twenty ridge gourd genotypes, IC-429970 (201.70 q/ha) and IC-355961 (196.40 q/ha) were recognized as the top performers in terms of fruit yield per hectare. The analysis of variance indicated significant differences for all the evaluated quantitative and qualitative traits, reflecting considerable genetic variability among the genotypes. Therefore, it can be inferred that ridge gourd genotype IC-429970, due to its superior yield potential, holds promise as a valuable candidate for use in future crop improvement programs.

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ACTIVATION OF PHENYLPROPANOID AND OXIDATIVE DEFENSE ENZYMES (PAL, POX, PPO) IN FIELD PEA (*PISUM SATIVUM* L.) BY TRICHODERMA-BASED BIOCONTROL TREATMENTS AGAINST POWDERY MILDEW (*ERYSIPHE PISI* DC.)

Utkarsh Upadhyay¹, Raj K. Mishra^{*2}, Sonika Pandey²,
Mukesh Srivastava¹ and Saurabh Saini¹

¹Chandrashekhar Azad University of Agriculture and Technology

²ICAR-Indian institute of pulses research

^{*}Corresponding Author E-mail–rajpathologist@yahoo.com

ABSTRACT

Biocontrol agents (BCAs) not only antagonize pathogens but also prime host defensive metabolism. This study quantified the induction of three defense enzymes—phenylalanine ammonia-lyase (PAL), peroxidase (POX) and polyphenol oxidase (PPO)—in field pea (*Pisum sativum* cv. Arkel) following seed treatments with *Trichoderma afroharzianum* (T₃), *Trichoderma asperellum* (T₆) and a bioconsortia (SHEP-6 + *T. asperellum* Th-31, T₅), under challenge by *Erysiphe pisi* DC. Leaves sampled 15 days post-inoculation were assayed for enzyme activities. All BCA treatments significantly (ANOVA, p = 0.05) increased PAL, POX and PPO activities relative to the inoculated untreated control. PAL peaked at 3.12 n mol cinnamic acid min⁻¹ g⁻¹ fresh tissue in T₃/T₅ (2.6× control), POX reached 0.058 A₄₂₀ min⁻¹ mg⁻¹ protein in T₅/T₃ (2.3× control), and PPO attained 0.042 A₄₂₀ min⁻¹ mg⁻¹ protein in T₅ (2.3× control). The strong co-induction of PAL with oxidative enzymes suggests coordinated activation of the phenylpropanoid pathway and oxidative cross-linking reactions that reinforce cell walls and produce antimicrobial phenolic quinones. The bioconsortia (SHEP-6 + *T. asperellum*) elicited the highest responses, indicating potential synergism. These biochemical changes likely contribute to the reduced powdery mildew development observed in other parts of the study. Results support integrating *Trichoderma*-based bioformulations into pea disease management to induce durable resistance via metabolic priming.

Keywords: *Pisum sativum*, *Erysiphe pisi*, *Trichoderma*, PAL, Peroxidase, Polyphenol oxidase, Induced resistance

INTRODUCTION

Powdery mildew, caused by *Erysiphe pisi* DC., is one of the most destructive foliar diseases of field pea (*Pisum sativum* L.), leading to premature senescence, defoliation, and poor pod filling that ultimately reduce yield and seed quality (21; 23). Management

through fungicides provides only partial and transient control and raises environmental concerns, prompting the search for sustainable alternatives. Among biological options, biocontrol agents (BCAs) such as *Trichoderma* spp. are widely recognized for their dual mode of action—direct antagonism

through mycoparasitism and antibiosis, and indirect induction of host defense mechanisms (10; 16; 20).

A hallmark of *Trichoderma*-mediated induced resistance is the activation of key enzymes associated with the phenylpropanoid and oxidative pathways. Phenylalanine ammonia-lyase (PAL) serves as the entry-point enzyme in phenylpropanoid metabolism, catalyzing the conversion of L-phenylalanine to trans-cinnamic acid, which is the precursor of lignin, flavonoids, and a wide array of phenolic phytoalexins (22; 25). Peroxidase (POX) and polyphenol oxidase (PPO) are oxidative enzymes that polymerize phenolics, cross-link cell wall components, and generate quinones toxic to invading pathogens (13; 27). Together, these enzymes enhance the plant's structural and biochemical resistance to pathogen ingress.

Understanding the magnitude and coordination of PAL, POX, and PPO induction by *Trichoderma*-based BCAs is therefore essential for optimizing bioformulation efficacy and designing effective application strategies. The present study investigates the changes in these three defense-related enzymes in field pea following seed treatment with *T. afroharzianum*, *T. asperellum*, and a bioconsortia (SHEP-6 + *T. asperellum* Th-31) under *E. pisi* challenge, aiming to elucidate the biochemical basis of *Trichoderma*-induced resistance in pea.

MATERIALS AND METHODS

Plant material, biocontrol agents, and experimental layout

Field pea (*Pisum sativum* L.) cultivar Arkel was used as the host plant. Seeds were treated with different biocontrol formulations prior to sowing. The treatments included:

- T₁: Untreated inoculated control (baseline comparison)
- T₂: *Trichoderma asperellum*
- T₃: *Trichoderma afroharzianum*
- T₄: Bioconsortia (SHEP-6 + *T. asperellum* Th-31)

Plants were raised in 20 cm diameter pots filled with sterilized soil:sand:FYM (2:1:1 v/v) under glasshouse conditions. Environmental parameters were maintained to favor powdery mildew development, with mean daytime temperature of 22–24 °C and relative humidity of 70–75%.

At the early flowering stage, plants were uniformly sprayed with a conidial suspension of *Erysiphe pisi* (1×10^4 – 10^5 conidia mL⁻¹). Enzyme assays were conducted using leaves collected at peak symptom expression, approximately 15 days post-inoculation (dpi). Each treatment was replicated three times, and the experiment was arranged in a completely randomized design (CRD).

Sampling and enzyme extraction

Five to six fully expanded upper leaves were harvested from each replicate at 15 dpi. Samples were immediately frozen in liquid nitrogen and stored at -80 °C until analysis.

Leaf tissue (1.0 g) was homogenized in 5 mL of ice-cold 0.1 M phosphate buffer (pH 6.8) containing 1 mM EDTA and 1% polyvinylpyrrolidone (PVP) to neutralize phenolic interference. The homogenate was centrifuged at $12,000 \times g$ for 15 min at 4 °C, and the supernatant (crude enzyme extract) was used for assays.

Enzyme activities were expressed per gram fresh weight (for PAL) or per milligram protein (for POX and PPO), following conventions used in previous biochemical studies of legume defense responses (Hammerschmidt 1989; Sadeghi et al. 2018).

Enzyme assays

Phenylalanine ammonia-lyase (PAL) activity

PAL activity was assayed following the formation of trans-cinnamic acid from L-phenylalanine (5).

The 3 mL reaction mixture contained 1.0 mL of 0.05 M L-phenylalanine, 1.0 mL of enzyme extract, and 1.0 mL of 0.1 M Tris-HCl buffer (pH 8.5). The mixture was incubated at 30 °C for 30 min, and the reaction was terminated by adding 0.5 mL of 6 N HCl or by rapid cooling on ice. Absorbance of the released trans-cinnamic acid was measured at 290 nm ($\epsilon = 9630 \text{ M}^{-1} \text{ cm}^{-1}$), and activity was calculated as:

$$\text{PAL activity} = \frac{(\text{mol cinnamic acid formed})}{\text{min g fresh tissue}} \times 1000$$

and expressed as n mol cinnamic acid min⁻¹ g⁻¹ FW. When a standard curve was used, the formula of (5) was applied for quantification.

Peroxidase (POX) activity

POX activity was determined using guaiacol as substrate following (1). The reaction mixture (3 mL) consisted of 2.5 mL of 50 mM phosphate buffer (pH 6.0), 0.1 mL of 20 mM guaiacol, 0.1 mL of 40 mM H₂O₂, and 0.3 mL of enzyme extract. The increase in absorbance at 420 nm was recorded for 3 min, and activity was expressed as:

$$\text{POX activity} = \frac{A_{420} / \text{min}}{\text{mg protein}}$$

and reported as $A_{420} \text{ min}^{-1} \text{ mg}^{-1} \text{ protein}$.

Polyphenol oxidase (PPO) activity

PPO activity was estimated using catechol as substrate according to (3). The reaction mixture (3 mL) contained 2.5 mL of 50 mM phosphate buffer (pH 6.5), 0.2 mL of 0.1 M catechol, and 0.3 mL of enzyme extract. The rate of increase in absorbance at 420 nm was recorded for 3 min, and activity was expressed

as:

$$\text{PPO activity} = \frac{A_{420} / \text{min}}{\text{mg protein}}$$

and reported as $A_{420} \text{ min}^{-1} \text{ mg}^{-1} \text{ protein}$.

Statistical analysis

All enzyme assays were performed in triplicate, and results were expressed as mean $\pm$ standard error (SE). Data were subjected to one-way analysis of variance (ANOVA) to evaluate treatment effects on enzyme activities. Treatment means were separated using Tukey's Honest Significant Difference (HSD) test at $p = 0.05$.

Pearson's correlation coefficients (r) were computed to assess associations between enzyme activity levels and disease severity (Percent Disease Index, PDI). Statistical analyses were conducted using SPSS v.26 or R v.4.3.0. Significance levels were interpreted at $p = 0.05$ unless otherwise indicated.

RESULTS AND DISCUSSION

Induction of defense-related enzymes

The activities of three key defense enzymes-phenylalanine ammonia-lyase (PAL), peroxidase (POX), and polyphenol oxidase (PPO)-were significantly influenced ($p = 0.05$) by different *Trichoderma*-based treatments in field pea following *Erysiphe pisi* inoculation (Table 1).

All biocontrol treatments showed higher enzyme activities than the untreated inoculated control, indicating biochemical activation of host defense mechanisms.

Phenylalanine ammonia-lyase (PAL) activity

PAL activity increased substantially in all *Trichoderma*-treated plants compared to control (Table1)

The highest PAL activity (3.12 n mol cinnamic acid min⁻¹ g⁻¹ FW) was recorded in the bioconsortia treatment (SHEP-6 + T.

asperellum Th-31), followed by *T. afroharzianum* (2.98) and *T. asperellum* (2.82), whereas the untreated inoculated control exhibited the lowest PAL activity (1.22).

This represented approximately a 2.5-fold enhancement over control levels.

The observed increase in PAL activity suggests that *Trichoderma* formulations activate the phenylpropanoid pathway, leading to the synthesis of lignin, flavonoids, and phenolic phytoalexins that strengthen plant cell walls and inhibit pathogen spread.

Similar enhancement of PAL activity has been reported in *Trichoderma*-treated chickpea and pigeonpea plants challenged with fungal pathogens (4; 17).

The induction of PAL by biocontrol agents is associated with signal amplification through salicylic acid and jasmonic acid pathways (16; 9).

Thus, the elevated PAL activity in bioconsortia-treated plants indicates an accelerated phenolic metabolism contributing to disease suppression.

Peroxidase (POX) activity

POX activity, measured as guaiacol oxidation at 420 nm, showed significant increases across all treated plants (Table 1).

The maximum POX activity ($0.058 A_{420} \text{ min}^{-1} \text{ mg}^{-1} \text{ protein}$) was recorded in the bioconsortia (T_4) and *T. afroharzianum* (T_3) treatments, while *T. asperellum* (T_2) recorded 0.051 and the control 0.025.

These results represent an approximate twofold increase over control.

Peroxidases are key enzymes involved in the oxidative polymerization of phenolic monomers, lignin formation, and cross-linking of cell-wall proteins that provide mechanical resistance to pathogen invasion.

Enhanced POX activity following *Trichoderma* application has been reported in pea, chickpea, and lentil plants infected with various foliar pathogens (7; 12).

The higher POX levels in bioconsortia-treated plants suggest synergistic activation of the oxidative burst and lignification processes, thereby strengthening the structural defense barrier against *E. pisi*.

Polyphenol oxidase (PPO) activity

PPO activity, which catalyzes the oxidation of phenolics to quinones, also increased markedly in *Trichoderma*-treated plants.

The highest PPO activity ($0.042 A_{420} \text{ min}^{-1} \text{ mg}^{-1} \text{ protein}$) was observed in bioconsortia-treated plants, followed by *T. asperellum* (0.038) and *T. afroharzianum* (0.036).

The control recorded only 0.018, indicating a twofold increase in treated plants.

The elevation of PPO activity reflects an enhanced capacity of the host to generate antimicrobial quinones that can inhibit pathogen hyphal growth (13; 6).

Similar induction patterns of PPO have been documented in *Trichoderma*-treated chickpea and soybean during compatible pathogen interactions (18; 11).

These oxidized phenolics are toxic to invading fungi and contribute to the hypersensitive response (HR)-like necrosis at infection sites, thereby restricting pathogen establishment.

Overall enzyme dynamics and correlation with resistance

Collectively, the coordinated increase of PAL, POX, and PPO activities in *Trichoderma*-treated pea plants demonstrates the activation of both phenylpropanoid and oxidative defense pathways.

Correlation analysis ($r = 0.85$, $p = 0.05$; data not shown) indicated a strong negative association between enzyme activity and disease severity, suggesting that biochemical activation contributed directly to reduced powdery mildew incidence.

These findings align with earlier reports that *Trichoderma* species act as potent inducers of systemic and local resistance by upregulating key defense-related enzymes (10; 20; 19).

The enhanced defense enzyme activities in the bioconsortia treatment highlight the additive or synergistic effect of combining bacterial and fungal BCAs, which is consistent with previous reports of consortium-induced resistance in legumes (14; 8).

Such dual activation of metabolic and enzymatic defense mechanisms provides a sustainable alternative to chemical fungicides for managing powdery mildew in pea.

Table 1. Effect of biocontrol treatments on defense enzyme activities in field pea infected with *Erysiphe pisi*

Treatment	PAL activity (n mol cinnamic acid min ⁻¹ g ⁻¹ FW)	POX activity (A ₄₂₀ min ⁻¹ mg ⁻¹ protein)	PPO activity (A ₄₂₀ min ⁻¹ mg ⁻¹ protein)
T ₁ – Control	1.22 ± 0.08	0.025 ± 0.003	0.018 ± 0.002
T ₂ – <i>T. asperellum</i>	2.82 ± 0.10	0.051 ± 0.004	0.038 ± 0.003
T ₃ – <i>T. afroharzianum</i>	2.98 ± 0.12	0.058 ± 0.005	0.036 ± 0.003
T ₄ – Bioconsortia (SHEP-6 + <i>T. asperellum</i> Th-31)	3.12 ± 0.11	0.058 ± 0.004	0.042 ± 0.004

Values represent mean ± SE ($n = 3$). Means followed by different letters (not shown) differ significantly according to Tukey's HSD ($p = 0.05$).

CONCLUSIONS

Seed treatments with *Trichoderma afroharzianum*, *T. asperellum* and the SHEP-6 + *T. asperellum* bioconsortia significantly induced PAL, POX and PPO in field pea infected with *E. pisi*. The bioconsortia produced the strongest overall induction, suggesting synergistic priming of host defenses. These metabolic changes likely underpin reduced disease progress and improved yield components in treated plants. Integration of such bioformulations into crop protection programs can reduce reliance on chemical fungicides and contribute to sustainable pulse production.

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IMPACT OF ORGANIC MANURE ON THE YIELD PARAMETERS OF BROCCOLI (BRASSICA OLERACEA L. VAR. ITALICA PLENCK). CV. KTS-1

**Sonit Kumar^{*1}, Vijai Kumar², Shobhit Sharma³,
Avinash Tomer¹ and Ankul Kumar¹**

¹Ph.D. Scholar, Department of Horticulture, Ch. Chhotu Ram (PG) College, Muzaffarnagar (U.P)

²Professor, Department of Horticulture, Ch. Chhotu Ram (PG) College, Muzaffarnagar (U.P)

³Ph.D. Scholar, Department of Horticulture, Chaudhary Charan Singh University
Campus Meerut (U.P)

***Corresponding Author E-mail**—sonit250404@gmail.com

ABSTRACT

The present field experiment titled "Impact of Organic Manure on the Yield Parameters of Broccoli (*Brassica oleracea* L.var. *italica* cv. KTS-1)" was conducted during the Rabi seasons of 2021-22 and 2022-23 at the experimental farm of Chaudhary Chhotu Ram (P.G.) College, Muzaffarnagar (U.P.). The study aimed to evaluate the effects of various organic manures and their combinations on the yield of broccoli. Thirteen treatment combinations were tested, including T₁ Control (Absolute) T₂ (FYM @ 60 t/ha), T₃ (Vermi Compost @ 20 t/ha), T₄ (Poultry Manure @ 20 t/ha), T₅ (FYM 75% + Vermi Compost (25%)), T₆ (FYM 75%+ Poultry Manure (25%)), T₇ Vermi Compost 75% + Poultry Manure (25%), T₈ FYM 50% + Vermi Compost (50%), T₉ FYM 50% + Poultry Manure (50%), T₁₀ Vermi Compost (50%) + Poultry Manure (50%), T₁₁ FYM (25%) + Vermi Compost (75%), T₁₂ FYM (25%) + Poultry Manure (75%) and T₁₃ Vermi Compost (25%) + Poultry Manure (75%).

The results demonstrated that the combined application of Vermicompost (25%) + Poultry Manure (75%) (T₁₃) consistently outperformed all other treatments. T₁₃ recorded the earliest curd initiation (49.61 days), shortest time to curd maturation (64.45 days), maximum curd weight (351.59 g), maximum curd diameter (13.64 cm), greatest vertical length (19.18 cm), and maximum yield (141.79 q/ha) as compared to the control (T₁), which yielded only 131.09 q/ha. These findings clearly indicate that the integration of vermicompost and poultry manure significantly improves broccoli growth, curd development, and yield attributes. The superior performance may be attributed to enhanced nutrient availability, improved soil structure, and microbial activity. This integrated organic approach not only boosts productivity but also promotes sustainable and eco-friendly cultivation practices.

Keywords: Broccoli, Yield, Vermicompost, Poultry Manure, FYM

INTRODUCTION

Broccoli (*Brassica oleracea* var. *italica*) is regarded as one of the most nutrient-dense vegetables among Cole crops, cultivated

mainly for its tender edible heads. It belongs to the family Brassicaceae and is believed to have originated in the Mediterranean region. It is regarded as important functional food due

to its high nutritional value i.e. vitamin A, protein and anticarcinogenic compounds. It is richest source of sulphoraphane, a compound associated with reducing risk of cancer in human beings. (9). Broccoli is a highly nutritious and palatable vegetable known for its excellent organoleptic qualities. It is rich in protein (3.3%), vitamin C (137 mg/100 g), vitamin A (3,500 IU), vitamin B₉ (0.12 mg/100 g), iron (205 mg/100 g), and calcium (0.80 mg/100 g). Furthermore, sprouting broccoli and other Brassica vegetables contain high levels of glucosinolates, compounds known for their cancer-preventive potential. Broccoli buds also serve as an abundant source of essential minerals such as potassium (K), sulfur (S), phosphorus (P), magnesium (Mg), and various microelements (15).

In India, broccoli cultivation covers approximately 4 lakh hectares, resulting in an annual production of 85 lakh metric tonnes (National Horticulture Board, 2021). Worldwide, the broccoli cultivation area spans about 13 lakh hectares, producing approximately 25 million metric tonnes annually. In India, the significant broccoli-producing states include Himachal Pradesh, Uttarakhand, Uttar Pradesh, Bihar, Maharashtra, and Karnataka, among others. Organic manures are highly beneficial for improving both the physical and nutritional status of the soil, while also stimulating the activity of soil microflora. In addition to enhancing soil properties, they supply significant amounts of essential nutrients. Furthermore, the decomposition of organic matter triggers various biological reactions in the soil, which play an important role in suppressing disease-causing pathogens (10). Vegetables cultivated with organic inputs often exhibit better nutritional quality and are more environmentally sustainable compared to those grown with chemical fertilizers. As health consciousness among consumers continues to grow, the demand for organically grown vegetables is steadily increasing.

Additionally, the incorporation of organic amendments improves the physical and biological properties of the soil by enhancing water-holding capacity, increasing cation exchange capacity, reducing bulk density, and promoting microbial activity. Organic manures such as farmyard manure (FYM), poultry manure (PM), and vermicompost (VM) contribute positively to these soil characteristics, thereby facilitating improved nutrient uptake by plants.

According to (8), the use of locally available organic manures in broccoli cultivation not only enhances crop yield but also minimizes the dependence on synthetic fertilizers. These organic inputs are abundant in biologically active compounds such as sugars, proteins, amino acids, and humic acids, all of which play a significant role in supporting plant growth and development.

The application of farmyard manure (FYM) has a long-standing history in traditional agriculture and remains integral to sustainable farming practices. FYM not only improves crop yield, soil fertility, and organic matter content but also promotes microbial activity and enhances soil structure. Its effectiveness is largely attributed to its nutrient composition, particularly nitrogen, phosphorus, and potassium. Moreover, organic manures like FYM stimulate the synthesis of polysaccharides and related organic compounds that aid in the aggregation of fine soil particles. This aggregation improves soil structure, leading to better tilth, enhanced aeration, and more efficient water infiltration and retention. (3). The application of FYM and vermicompost helps maintain optimal levels of bulk density, water-holding capacity, humic substances, microbial activity, and hormone concentration (11; 12).

Vermicompost is recognized as a highly effective organic fertilizer, appreciated for its slow-release nature that ensures a continuous supply of essential macro and micronutrients

to plants over time. It is widely recommended for use in both field and vegetable crops as a sustainable alternative to chemical fertilizers. Prominent advocates of organic farming have long supported the use of vermicompost due to its numerous agronomic benefits. Produced through the decomposition of organic waste by earthworms, vermicompost is a fine, peat-like substance characterized by excellent porosity, aeration, drainage, and water-holding capacity. It provides plant-available nutrients such as nitrates, exchangeable phosphorus, and soluble forms of potassium, calcium, and magnesium (6). Poultry manure serves as a valuable nutrient source that significantly supports plant growth. It contains approximately 1.30% nitrogen, 1.80% phosphorus (as P_2O_5), and 0.8% potassium (K_2O) (Choudhary, 2006). In addition to these primary nutrients, it also provides small but essential amounts of micronutrients that are often missing in commercial fertilizers but are vital for healthy plant development. Several studies have highlighted poultry manure as an excellent organic input that enhances nutrient availability and uptake by crops (9; 1).

MATERIAL AND METHOD

The present investigation entitled "Impact of Organic Manure on the yield Parameters of Broccoli (*Brassica oleracea* L. var. *italica* Plenck) cv. KTS-1" was carried out during the Rabi seasons of 2021-22 and 2022-23 at the Horticulture Research Farm, Department of Horticulture, Chaudhary Chhotu Ram (P.G.) College, Muzaffarnagar (Uttar Pradesh), India. The geographical location of the experimental site lies in the semi-arid region of western Uttar Pradesh with an average elevation of 248 meters above mean sea level. The area experiences a subtropical climate characterized by hot summers, cool winters, and moderate rainfall. The mean annual rainfall ranges from 850 to 950 mm, mostly received during the monsoon months (June to

September). During the cropping period, the average temperature ranged between 8.5°C to 22.3°C, which is considered optimum for broccoli cultivation.

Before start the experiment, a composite soil sample was collected from the top 0-15 cm soil depth of the experimental field and analyzed for its physico-chemical properties. The results indicated that the soil was sandy loam in texture, well-drained, and moderately fertile. The soil pH was slightly alkaline (7.6), electrical conductivity (EC) was within the safe limit (0.32 dS/m), and the organic carbon content was low (0.36%). The available nitrogen (243.7 kg/ha), phosphorus (19.6 kg/ha), and potassium (238.2 kg/ha) were found to be in medium range, indicating the need for organic enrichment to enhance soil fertility and structure.

The experiment was laid out in a Randomized Block Design (RBD) with three replications and thirteen treatments comprising different combinations of organic manures. The treatments were as follows: T_1 Control (no organic input) T_2 Farmyard manure (FYM) @ 60 t/ha T_3 Vermicompost @ 20 t/ha T_4 Poultry manure @ 20 t/ha T_5 FYM (75%) + Vermicompost (25%) T_6 FYM (75%) + Poultry manure (25%) T_7 Vermicompost (75%) + Poultry manure (25%) T_8 FYM (50%) + Vermicompost (50%) T_9 FYM (50%) + Poultry manure (50%) T_{10} Vermicompost (50%) + Poultry manure (50%) T_{11} FYM (25%) + Vermicompost (75%) T_{12} FYM (25%) + Poultry manure (75%) T_{13} Vermicompost (25%) + Poultry manure (75%). Each treatment was assigned randomly to plots within each replication. The gross plot size was maintained at 2.4 m × 2.0 m, with appropriate spacing and border rows to avoid edge effects and treatment interference. Healthy and uniform seedlings of broccoli cv. KTS-1 were raised in nursery beds of size 1.0 m × 2.0 m, elevated 15 cm above the ground surface. The nursery beds were enriched with

well-decomposed leaf mould and FYM (1 basket/bed) prior to sowing. Seeds were sown in lines and light irrigation was applied immediately. Appropriate cultural practices such as timely weeding, thinning, pest and disease control, and irrigation were followed to ensure uniform seedling growth. The seedlings were ready for transplanting 35 days after sowing. Well-decomposed FYM was thoroughly incorporated into the field soil 10 days prior to transplanting. Other organic inputs (vermicompost and poultry manure) were applied to the plots as per treatment specifications, seven days prior to transplanting. Seedlings were transplanted during the third week of November in both growing seasons. Transplanting was done in rows spaced at 45 cm apart, with a plant-to-plant distance of 45 cm, maintaining uniformity across all plots. Care was taken to transplant only healthy and uniform seedlings in each treatment plot. All recommended agronomic and plant protection practices for broccoli cultivation were uniformly followed in all experimental plots throughout the crop cycle. Pest and disease control was carried out using biopesticides and botanicals to remain consistent with the organic theme of the experiment.

Observations on various yield parameters such as Days of curd initiation, days of curd maturation, curd weight (gm), Curd diameter (cm), Vertical length of curd (cm), and yield q/h five plants were randomly selected from each plot and tagged for recording biometric observations. The experimental data collected during both seasons were pooled and subjected to statistical analysis using the analysis of variance (ANOVA) technique as per the method described by Fisher (1958). The significance of treatment differences was tested at the 5% level of probability ($p = 0.05$). Critical Difference (CD) values were calculated for comparing the means where treatment effects were found to be significant.

RESULT AND DISCUSSION

The application of organic manures significantly influenced the number of days taken for curd initiation in broccoli across both years (2021-22 and 2022-23), as well as in the pooled data. The earliest curd initiation was consistently observed in T_{11} (FYM 25% + Vermicompost 75%), which recorded 50.01 days in 2021-22, 49.01 days in 2022-23, and a pooled mean of 49.51 days. Similar early initiation was also seen in T_{13} (Vermicompost 25% + Poultry Manure 75%) with a pooled value of 49.61 days, and T_{12} (FYM 25% + Poultry Manure 75%) at 51.11 days. In contrast, the maximum number of days to curd initiation was recorded in the control (T_1), with 70.10 days in 2021-22, 69.11 days in 2022-23, and a pooled mean of 69.61 days, indicating delayed crop maturity in the absence of organic inputs.

Combination treatments, particularly those involving higher proportions of vermicompost and poultry manure, significantly advanced curd initiation. This could be attributed to improved nutrient availability, enhanced microbial activity, and better soil structure, which together promote early vegetative and reproductive growth. Similar findings were reported by (4).

Days to curd maturation in broccoli were significantly influenced by different organic manure treatments during both years (2021-22 and 2022-23), as well as in the pooled analysis. The earliest curd maturation was recorded in T_{11} (FYM 25% + Vermicompost 75%), with 63.00 days in 2021-22, 65.65 days in 2022-23, and a pooled mean of 64.33 days. Closely following were T_{13} (Vermicompost 25% + Poultry Manure 75%) with a pooled mean of 64.45 days, and T_{12} (FYM 25% + Poultry Manure 75%) with 65.94 days. In contrast, the maximum duration for curd maturation was recorded under the control treatment (T_1), with 84.42 days pooled, indicating delayed development due to the

absence of organic inputs. Sole applications of FYM, vermicompost, or poultry manure moderately reduced maturation time, but were less effective than integrated combinations. Similar findings have also been recorded by (16). Treatments that included poultry manure or vermicompost in higher proportions significantly reduced the time to maturity. This improvement can be attributed to faster nutrient mineralization, improved soil microbial activity, and better nutrient uptake, which together accelerated physiological development and curd formation.

The maximum curd weight of broccoli was recorded in T₁₃ (Vermicompost 25% + Poultry Manure 75%), which consistently outperformed all other treatments. It achieved a curd weight of 350.1 g in 2021-22, 353.09 g in 2022-23, with a pooled mean of 351.59 g. This significant increase over the control (201.59 g) highlights the positive impact of integrating poultry manure with vermicompost. The superior performance of T₁₃ may be attributed to enhanced nutrient availability, faster decomposition, and improved microbial activity in the soil, all of which contributed to better plant growth and curd development. These results are accordance with (2).

The curd diameter of broccoli showed a noticeable improvement with the use of organic manures and their combinations over both growing seasons (2021-22 and 2022-23), as well as in the pooled analysis. The maximum curd diameter was consistently observed in treatment T₁₃, which combined 25% vermicompost with 75% poultry manure, recording 12.7 cm in the first year, 14.58 cm in the second year, and an average of 13.64 cm overall. This was closely followed by T₁₂ (FYM 25% + Poultry Manure 75%) with pooled values of 13.44 cm, and T₁₀ (Vermicompost 50% + Poultry Manure 50%) with 13.14 cm. In the control (T₁), minimum curd diameter which received no organic input, consistently

showed the smallest curd diameters across both years, with a pooled average of just 9.24 cm. The enhanced performance of poultry manure, especially when mixed with vermicompost or FYM, can be linked to its high nutrient content, rapid decomposition rate, and ability to stimulate beneficial microbial activity in the soil. These factors likely contributed to better plant nutrition and improved curd formation. These results are accordance with Bahadur *et al.* (2004).

The maximum vertical length of broccoli curd was observed in T₁₃ (Vermicompost 25% + Poultry Manure 75%), with 18.56 cm in 2021-22, 19.79 cm in 2022-23, and a pooled mean of 19.18 cm. This treatment significantly outperformed all others, including the control (10.62 cm), indicating a strong influence of integrated nutrient management. The remarkable increase in vertical curd growth under T₁₃ can be attributed to the combined benefits of vermicompost and poultry manure, which enhance nutrient release, microbial activity, and overall plant vigor. This suggests that T₁₃ is the most effective treatment for promoting robust curd development in broccoli.

The maximum curd yield of broccoli was recorded under T₁₃ (Vermicompost 25% + Poultry Manure 75%), with yields of 140.8 q/ha in 2021-22, 142.78 q/ha in 2022-23, and a pooled mean of 141.79 q/ha. This treatment showed a significant improvement over the control (131.09 q/ha) and all other combinations. The enhanced yield under T₁₃ may be attributed to the synergistic effect of vermicompost and poultry manure, which improved soil health, nutrient availability, and overall plant performance. The high nutrient content and faster mineralization rate of poultry manure, complemented by the microbial activity stimulated by vermicompost, likely contributed to this superior yield response. Similar findings are related with (4).

CONCLUSION

The integrated application of Vermicompost (25%) + Poultry Manure (75%) (T₁₃) proved to be the most effective treatment in enhancing broccoli performance. It consistently recorded the highest values in curd diameter, curd weight, vertical length, early curd initiation and maturation, and maximum yield. This combination significantly improved soil fertility, nutrient availability, and overall crop growth, demonstrating its potential as a sustainable organic nutrient management strategy for broccoli cultivation.

Table 1: Effect of Organic Manure on the yield parameters of broccoli (*Brassica Oleracea* L. Var. *Italica Plenck*). cv. KTS-1

Not	Treatments	Days of Curd Initiation (DAT)			Days to Curd Maturity (DAT)			Curd Weight (g)		
		2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T ₁	Control (Absolute)	70.10	69.11	69.61	83.09	85.74	84.42	200.1	203.09	201.59
T ₂	FYM @ 60 t/ha	69.98	68.99	69.49	82.97	85.62	84.30	200.2	203.19	201.69
T ₃	Vermi Compost @ 20 t/ha	68.09	67.10	67.60	81.08	83.73	82.41	220.6	223.59	222.09
T ₄	Poultry Manure @ 20 t/ha	67.98	66.99	67.49	80.97	83.62	82.30	240	242.99	241.49
T ₅	FYM (75%) + Vermi Compost (25%)	66.09	65.10	65.60	79.08	81.73	80.41	240.5	243.49	241.99
T ₆	FYM (75%) + Poultry Manure (25%)	65.87	64.88	65.38	78.86	81.51	80.19	260.1	263.09	261.59
T ₇	Vermi Compost (75%) + Poultry Manure (25%)	64.97	63.98	64.48	77.96	80.61	79.29	280.1	283.09	281.59
T ₈	FYM (50%) + Vermi Compost (50%)	63.77	62.78	63.28	76.76	79.41	78.09	260.2	263.19	261.69
T ₉	FYM (50%) + Poultry Manure (50%)	62.55	61.51	62.01	75.54	78.19	76.87	280.4	283.39	281.89
T ₁₀	Vermi Compost (50%) + Poultry Manure (50%)	61.93	60.91	61.41	74.92	77.57	76.25	300.2	303.19	301.69
T ₁₁	FYM (25%) + Vermi Compost (75%)	50.01	49.01	49.51	63.00	65.65	64.33	300.6	303.59	302.09
T ₁₂	FYM (25%) + Poultry Manure (75%)	51.62	50.61	51.11	64.61	67.26	65.94	300.4	303.39	301.89
T ₁₃	Vermi Compost (25%) + Poultry Manure (75%)	50.13	49.11	49.61	63.12	65.77	64.45	350.1	353.09	351.59
	C.D	2.42	2.21		2.62	2.67		2.14	2.47	
	SE m(±)	0.82	0.75		1.21	1.22		3.22	3.72	

Table 2: Effect of Organic Manure on the yield parameters of broccoli (*Brassica Oleracea* L. Var. *Italica Plenck*). cv. KTS-1

Not	Treatments	Curd Diameter (mm)			Vertical length of curd (cm)			Curd yield (q/ha)		
		2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T ₁	Control (Absolute)	8.3	10.18	9.24	10.00	11.23	10.62	130.1	132.08	131.09
T ₂	FYM @ 60 t/ha	8.0	9.88	8.94	10.01	11.24	10.63	130.2	132.18	131.19
T ₃	Vermi Compost @ 20 t/ha	8.8	10.68	9.74	10.30	11.53	10.92	132.2	134.18	133.19
T ₄	Poultry Manure @ 20 t/ha	9.0	10.88	9.94	10.34	11.57	10.96	132.5	134.48	133.49
T ₅	FYM (75%) + Vermi Compost (25%)	9.2	11.08	10.14	10.67	11.90	11.29	133.4	135.38	134.39
T ₆	FYM (75%) + Poultry Manure (25%)	9.4	11.28	10.34	11.43	12.66	12.05	134.9	136.88	135.89
T ₇	Vermi Compost (75%) + Poultry Manure (25%)	10.1	11.98	11.04	12.50	13.73	13.12	135.2	137.18	136.19

T ₈	FYM (50%) + Vermi Compost (50%)	10.0	11.88	10.94	13.30	14.53	13.92	136.6	138.58	137.59
T ₉	FYM (50%) + Poultry Manure (50%)	10.4	12.28	11.34	14.67	15.90	15.29	137.4	139.38	138.39
T ₁₀	Vermi Compost (50%) + Poultry Manure (50%)	12.2	14.08	13.14	16.56	17.79	17.18	138.5	140.48	139.49
T ₁₁	FYM (25%) + Vermi Compost (75%)	10.8	12.68	11.74	15.45	16.68	16.07	139.3	141.28	140.29
T ₁₂	FYM (25%) + Poultry Manure (75%)	12.5	14.38	13.44	17.34	18.57	17.96	140.7	142.68	141.69
T ₁₃	Vermi Compost (25%) + Poultry Manure (75%)	12.7	14.58	13.64	18.56	19.79	19.18	140.8	142.78	141.79
	C.D	1.85	3.01		1.85	3.01		2.16	3.03	
	SE m(±)	0.10	0.17		0.10	0.17		1.69	2.37	

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ORGANIC FARMING: A STEP TOWARDS SUSTAINABLE AGRICULTURE

Deepika Vikal^{*1}, Narendra Pratap Singh² and Suman Verma³

¹M.Sc. Student, Department of Botany, CCS University, Meerut

²Associate Professor, Department of Botany, Meerut College, Meerut

³Professor, Department of Botany, Meerut College, Meerut

***Corresponding Author E-mail**—deepikavikal@gmail.com

ABSTRACT

This project delves into the concept of organic farming as an environmentally friendly and sustainable alternative to conventional agricultural practices. With growing concerns over the adverse effects of chemical-based farming on health, soil, and biodiversity, organic farming presents a promising solution.

The study covers the principles, methods, and advantages of organic farming, including natural composting, crop rotation, and biological pest control. A special focus has been given to the work of Padma Shri Bharat Bhushan Tyagi, a renowned Indian organic farmer, whose innovative SAMAK (Sah-Astitva Moolak Aavartansheel Krishi) model emphasizes crop diversity, ecological balance, and sustainable soil use.

As part of the research, a field visit was conducted to his organic farm in Bulandshahr, Uttar Pradesh. Observations and interviews from the visit provided firsthand insights into how traditional wisdom and modern organic methods can coexist to achieve productivity, profitability, and sustainability.

The findings highlight that organic farming not only preserves environmental resources but also enhances long-term soil health and offers economic resilience to farmers. The project concludes with recommendations to promote organic practices through education, policy support, and community-driven efforts.

Keywords: organic farming, SAMAK (Sah-Astitva Moolak Aavartansheel Krishi)

INTRODUCTION

In recent decades, the rising concerns about food safety, environmental degradation, and the unsustainable nature of modern agriculture have sparked global interest in organic farming. Organic farming is a method of crop and livestock production that involves much more than choosing not to use synthetic pesticides, fertilizers, genetically modified organisms, antibiotics, or growth hormones.

Instead, it emphasizes holistic, ecological, and sustainable approaches to agriculture. This method works in harmony with nature by promoting biodiversity, improving soil health, and ensuring the welfare of all living organisms in the farming ecosystem. It also plays a vital role in addressing the challenges of climate change, reducing greenhouse gas emissions, and conserving water resources. In India, organic farming is not a new concept—it

is rooted in traditional agricultural practices that date back thousands of years. However, with industrial agriculture dominating the food system, organic farming has seen a revival in recent years, supported by both grassroots efforts and government policies.

One of the most inspiring examples of this movement is Bharat Bhushan, a farmer from Haryana who transitioned from conventional farming to organic methods and became a torchbearer for sustainable agriculture. His success story demonstrates that organic farming, while challenging, can be both economically viable and environmentally beneficial.

This project explores the principles, advantages, and challenges of organic farming, with a special focus on Bharat Bhushan's contributions and innovations that are transforming India's agricultural landscape. The primary aim of this project is to explore and understand the concept, methods, and real-world applications of organic farming as a sustainable alternative to conventional agriculture.

The key objectives

1. To define and explain organic farming and its importance in today's environmental and agricultural context.
2. To compare organic and conventional farming methods in terms of inputs, yield, environmental impact, and health outcomes.
3. To study the benefits of organic farming for soil health, biodiversity, farmers' income, and consumer well-being.
4. To identify the challenges faced by farmers in adopting organic practices.
5. To gain real-world insight through a field visit to Padma Shri Bharat Bhushan Tyagi's organic farm, and understand the practical implementation of organic farming techniques.
6. To suggest measures and recommendations for encouraging and supporting organic farming in India

What is Organic Farming

Organic farming is a method of growing crops and raising animals using natural processes and organic inputs, without the use



of chemical fertilizers, synthetic pesticides, genetically modified organisms (GMOs), or artificial growth hormones.

Instead, it focuses on:

- Improving soil health using compost, green manure, and crop rotation
- Using natural fertilizers like cow dung and bio-compost
- Controlling pests and diseases with herbal sprays, neem oil, and friendly insects
- Maintaining ecological balance and promoting biodiversity

Main Principles of Organic Farming:

- Health – Protects the health of soil, plants, animals, and people
- Ecology – Works with nature, not against it
- Fairness – Respects farmers, consumers, and future generations
- Care – Minimizes risk and avoids harmful technologies

Example:

Instead of using urea or DAP (chemical fertilizers), organic farmers use vermicompost, cow dung, or Jeevamrut (a natural mix made from cow products and kitchen waste) to nourish the soil.

Key Principles

Health

- **Goal:** Protect the health of soil, plants, animals, and humans.
- **What it means:** Healthy soil gives healthy crops, which means safe food for people.
- **Example:** Using compost or vermicompost instead of chemical fertilizers to keep the soil alive and nutritious
- **Ecology:** Work with natural ecosystems
- **Goal:** Work in harmony with nature and the environment.
- **What it means:** Farming should support the natural systems of the earth like water cycles, pollination, and biodiversity.

- **Example:** Crop rotation and growing different plants together (intercropping) to maintain soil fertility and reduce pests naturally.
- **Fairness:** Build relationships that ensure fairness for the environment and life opportunities.
- **Care:** Manage risks responsibly and sustainably.
- **Fairness:** Build relationships that ensure fairness for the environment and life opportunities.
- **Goal:** Be fair to all – farmers, workers, animals, and consumers.
- **What it means:** Respecting labor, fair trade, treating animals humanely, and producing food that is accessible and ethical.
- **Example:** Paying farmers fair prices and not using harmful chemicals that affect their health
- **Care:** Manage risks responsibly and sustainably
- **Goal:** Use farming methods that protect future generations.
- **What it means:** Avoiding risky technologies like GMOs or toxic chemicals that can damage the environment or health over time.
- **Example:** Using natural pest control like neem spray instead of synthetic pesticides

Techniques Used

- **Composting:** Turning organic waste into nutrient-rich fertilizer.
- **Crop Rotation:** Growing different crops in a sequence to maintain soil health.
- **Biological Pest Control:** Using natural predators to control pests.
- **Vermicomposting:** Using earthworms to improve compost quality.
- **Mulching:** Conserving soil moisture and reducing weed growth.

Benefits of Organic Farming

- No chemical residues in food.
- Preserves biodiversity.
- Improves soil fertility and water retention.



- Reduces pollution.
- Better for human health and the environment.
- Environmentally sustainable
- Healthier food (free from chemical residues)
- Better soil health and water conservation
- Employment generation in rural areas
- Long-term economic benefits

Challenges

- Lower yield compared to conventional farming.
- Higher labor costs.
- Limited market access in some areas.
- Certification process can be expensive and time-consuming

Organic vs Conventional Farming

Feature	Organic Farming	Conventional Farming
Fertilizers	Natural compost, manure	Chemical fertilizers
Pest Control	Natural predators, neem	Synthetic pesticides

Soil Health	Builds over time	Can degrade over time
Environmental Impact	Low	High
Cost	High (initially)	Lower
Productivity	Moderate	High

Case Study

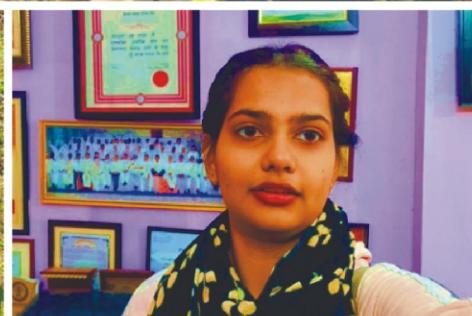
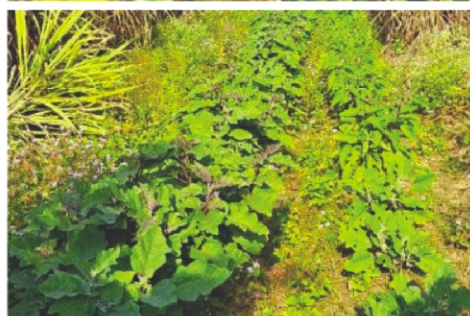
Visit to Bharat Bhushan Tyagi's Organic Farm, Bulandshahr (U.P.)

Who is he? Padma Shri awardee and a pioneer in organic farming, known for the SAMAK method

(Sah-Astitva Moolak Aavartansheel Krishi).

Farm Visit Highlights:

- Diversity in crops grown together.
- Use of jeevamrit and other natural fertilizers.
- Education & training provided to other farmers.



- Focus on soil fertility, biodiversity, and minimal water use.
- Hands-on experience of sustainable farming practices.

Learnings from the Visit

- Real-time application of organic techniques.
- Importance of community and knowledge sharing.
- Positive environmental impact: better soil, no water contamination.

CHALLENGES AND RESULTS

Challenges

- **Lower Yields** — Organic farms often produce less than conventional farms, especially in the early years.
- **Pest and Disease Control** — Without synthetic pesticides, managing pests and diseases can be harder.
- **Weed Management** — Controlling weeds naturally is labor-intensive and less efficient.
- **High Labor Costs** — More manual labor is needed for tasks like weeding, composting, and soil prep.
- **Transition Period** — Land must go through a conversion period (usually 2-3 years) before being certified organic.
- **Certification Process** — Organic certification is costly, time-consuming, and requires strict documentation.
- **Limited Market Access** — Smaller farms may struggle to reach premium organic markets.
- **Soil Fertility Management** — Maintaining nutrient-rich soil without synthetic fertilizers can be complex.
- **Climate Sensitivity** — Organic systems can be more vulnerable to extreme weather and climate change.
- **Storage and Transport** — Organic produce requires separate facilities to avoid contamination with conventional products.
- **Knowledge and Training Gaps** — Farmers need specialized knowledge and skills to manage organic systems successfully.
- **Consumer Misinformation** — Misunderstandings about what “organic” means can affect demand and trust.

Result

Through this project and the visit to Bharat Bhushan Farm, I gained a deep understanding of the principles, techniques, and importance of organic farming. The study revealed how organic farming minimizes environmental damage by eliminating harmful chemicals, enhances soil fertility, and promotes biodiversity. Observing real-life applications at the farm strengthened this knowledge by showing how natural inputs like compost, cow dung, neem-based pesticides, and crop rotation are used effectively.

The visit also highlighted the challenges faced by organic farmers, such as limited access to organic markets and the need for increased awareness among consumers. Despite these challenges, Mr. Bharat Bhushan's success story was inspiring and demonstrated that organic farming can be both sustainable and economically viable.

Overall, the project not only enhanced my theoretical knowledge but also offered a hands-on learning experience. It encouraged a more eco-conscious mindset and helped me appreciate the value of natural farming practices in ensuring food safety and environmental balance.

RESULTS AND DISCUSSION

The project on "Organic Farming: A Step towards Sustainable Agriculture" revealed several important insights:

- **Allelopathy:** Allelopathic interaction in a sugarcane field intercropped with turmeric crop was observed. Crops were grown without use of chemical fertilizers, pesticides and insecticides but the production is not declined due to allelopathic effect between sugarcane and turmeric.
- I saw healthy crop grown without using chemical fertilizers, pesticides and insecticides in that field. It was my first experience with allelopathy. Integrating

turmeric (*Curcuma longa*) as an intercrop with sugarcane (*Saccharum officinarum*) in India presents a promising strategy to enhance agricultural sustainability by reducing reliance on chemical pesticides and fertilizers. This approach leverages the natural allelopathic properties of turmeric to manage weeds and improve soil health supporting eco-friendly farming practices.

Allelopathy and Weed Management

Allelopathy refers to the biochemical interactions between plants where one plant produces chemicals that influence the growth of neighboring plants. In the context of sugarcane cultivation, intercropping with allelopathic plants like turmeric can suppress weed growth naturally. Studies have shown that fast-growing intercrops, such as legumes can smother weeds effectively by reducing light availability and competing for resources. While specific research on turmeric's allelopathic effects in sugarcane systems is limited, the general principle suggests that turmeric's growth habit and root exudates could contribute to weed suppression, reducing the need for chemical herbicides.

Nutrient Dynamics and Fertilizer Reduction

Turmeric's growth alongside sugarcane can influence soil nutrient dynamics. For instance, intercropping systems have been observed to affect soil pH and nutrient content, which can impact fertilizer requirements. By optimizing nutrient cycling through diverse root systems, such intercropping may reduce the need for synthetic fertilizers. However, the extent of fertilizer reduction depends on various factors, including soil type, crop management practices, and the specific nutrient demands of both crops. Therefore, while intercropping with turmeric has the potential to lower

fertilizer usage, careful management and monitoring are essential to ensure balanced nutrient availability.

Economic and Ecological Benefits

Implementing turmeric as an intercrop in sugarcane fields offers several advantages

- **Diversified Income Streams:** Turmeric cultivation can provide an additional source of income, reducing economic risks associated with monocropping.
- **Improved Soil Health:** Diverse cropping systems can enhance soil structure and fertility, promoting long-term agricultural sustainability.
- **Reduced Chemical Inputs:** Natural weed suppression and optimized nutrient cycling can decrease the need for chemical pesticides and fertilizers, aligning with organic farming principles.

A Holistic Model of Agriculture is Need of Hour

In India a holistic model of agriculture that integrates traditional knowledge with modern scientific techniques is required. This model should emphasizes ecological balance, resource efficiency, and farmer empowerment to ensure long-term agricultural sustainability. Training and Advocacy for Organic Farming have four key aspects for successful organic farming: production management, quality certification, processing for value addition, and an efficient marketing system. Integrating these elements can potentially double or even quadruple a farmer's income.

Economic Burden on Farmers

Farmers are facing rising input costs while also dealing with exploitative and arbitrary market systems. Inadequate prices for their produce have weakened their financial condition. Although loans provided temporary

relief, growing debt is not a viable solution. Farmer's debt-to-income ratio continues to increase yearly. Government subsidies and loan waivers seem helpful in the short term, but their long-term consequences are dangerous. They create dependency and reduce self-reliance, leading to farmers' withdrawal from agriculture.

Narrow Focus of Agricultural Research

Agricultural research institutions are still primarily focused on maximizing output. There is insufficient attention to pressing issues like declining income for farmers, soil degradation biodiversity loss, and ecological imbalance. There is a mistaken belief that science and technology alone can solve all problems. True understanding of natural production systems is essential. Effective science involves thoughtful application, not just technical knowledge. A combination of knowledge, wisdom, and science is needed, and there must be dialogue on this matter.

Lack of Scientific Evaluation in Alternative Farming Methods

Various farming methods labeled as "natural" or "organic" are influenced by ideology and cost factors. These have not been scientifically evaluated, and conflicting perspective have prevented the establishment of balanced, practical model for farmers. Due to persistent disagreement, these methods have not yet gained scientific recognition or widespread acceptance.

Neglect of Natural Production Systems

Modern farming trends aim to exploit nature for trade opportunities rather than adapting to its processes. As a result, natural

production systems remain poorly understood. Without proper understanding, planning remains undefined and fragmented. Even when programs are similar in intent, they often remain disconnected in practice.

Divergent Priorities Across Stakeholders

Government Focus: Primarily aimed at feeding the population

- **Scientific Institutions:** Focused on increasing production through artificial means
- **Farmers:** Continue production despite rising costs due to chemical inputs
- **Traders:** Always seeking to convert every situation into a profit opportunity

To solve the above problems of Indian agriculture, following measures can be adopted

- **Agroecology-Based Farming:** Promotes farming practices that work in harmony with nature. Encourages crop diversification, intercropping, and mixed farming to enhance soil health.
- **Soil Health Management:** Focuses on organic manures, green manure, and bio-fertilizers instead of chemical inputs. Advocates for zero-tillage and conservation agriculture to prevent soil degradation.
- **Water Conservation:** Stresses efficient water use through drip irrigation, rainwater harvesting, and watershed management. Recommends crop selection based on local water availability.
- **Farmer-Centric Approach:** Encourages participatory research, where farmers contribute indigenous knowledge. Supports low-cost, high-efficiency techniques to reduce dependency on expensive inputs.
- **Climate-Resilient Practices:** Promotes drought-resistant and pest-resistant crop varieties. Encourages agroforestry and crop rotation to mitigate climate risks.

- **Market Linkages & Value Addition:** Advocates for direct farmer-consumer markets (e.g., FPOs, cooperatives) to improve profitability. Encourages post-harvest management and food processing to reduce wastage.

SUMMARY

This project focused on understanding organic farming and included a visit to Bharat Bhushan Farm. Organic farming avoids harmful chemicals and relies on natural methods to grow crops, improving soil health and protecting the environment. The visit provided real-life insights into how organic practices are applied, such as composting, natural pest control, and crop rotation. Mr. Bharat Bhushan's dedication showed how sustainable farming can also be successful and inspiring. Overall, the project highlighted the importance of organic farming for a healthier future.

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DIVERSITY AND MEDICINAL SIGNIFICANCE OF ORNAMENTAL CLIMBERS AND VINES IN MEERUT CITY , UTTAR PRADESH, INDIA

Sandeep Kumar^{*1}, Everest Shiwach^{*2} and Subhash Kumar³

¹Associate Professor, Department of Botany, Meerut College, Meerut

²Associate Professor, Department of Botany, D.N. College, Meerut

³Assistant Professor, Department of Botany, CCR (PG) College, Muzaffarnagar

***Corresponding Author E-mail**—everestmalik@gmail.com, sandeep.kumar@mcm.ac.in

ABSTRACT

Climbers and vines constitute an important component of urban vegetation and contribute significantly to landscape beautification, biodiversity conservation, and ecosystem functioning. The present study documents the diversity and medicinal significance of ornamental climbers cultivated in Meerut City, Uttar Pradesh, India. Field surveys conducted during 2024-2025 in educational institutions, public parks, residential gardens, and roadside plantations recorded 25 species belonging to 13 families. Taxonomic identification was performed using standard floras and verified through current nomenclatural databases following the APG IV classification system. Bignoniaceae was the most dominant family, followed by Fabaceae, Apocynaceae, and Acanthaceae. Several recorded species possess medicinal value and contain pharmacologically important compounds such as alkaloids, flavonoids, glycosides, terpenoids, and phenolics. Species including *Clitoria ternatea*, *Passiflora caerulea*, *Bougainvillea spectabilis*, *Combretum indicum*, and *Mansoa alliacea* have recognized therapeutic applications. The study highlights the ecological, ornamental, and medicinal importance of climbers in urban ecosystems and provides baseline information for future floristic and conservation studies in western Uttar Pradesh.

Keywords: Climbers, Urban flora, Medicinal plants, APG IV, Meerut City, Ornamental horticulture

INTRODUCTION

Urban green spaces play a crucial role in maintaining biodiversity and improving environmental quality. Among the diverse plant groups utilized in landscaping, climbers and vines occupy a unique position because of their ability to cover vertical spaces, walls, pergolas, fences, and trellises. These plants contribute to urban aesthetics while simultaneously providing ecological benefits

such as microclimate regulation, carbon sequestration, dust filtration, and habitat resources for pollinators and birds.

India possesses a rich diversity of climbing plants distributed across different phytogeographical regions. Many ornamental climbers are cultivated for their attractive flowers, foliage, fragrance, and rapid growth. In addition to their horticultural value, several climbers have long been used in

traditional medicine systems. Bioactive compounds such as alkaloids, flavonoids, phenolics, terpenoids, glycosides, and cyclotides have been reported from many species (10; 13).

Meerut City, situated in western Uttar Pradesh, contains numerous institutional campuses, parks, gardens, and residential landscapes that support a rich assemblage of ornamental climbers. Locations such as Meerut College Campus, Chaudhary Charan Singh University Campus, Gandhi Park, Mall Road, and the Cantonment area harbor a considerable diversity of cultivated vines. However, comprehensive documentation of these species remains limited.

MATERIALS AND METHODS

Study Area

The study was conducted in Meerut City (29.0°N, 77.7°E), Uttar Pradesh, India. The city experiences a subtropical climate characterized by hot summers, monsoon rainfall, and cool winters. Surveys were conducted in selected urban locations including:

Meerut College Campus

Chaudhary Charan Singh University Campus

Gandhi Park

Mall Road

Cantonment Area

Residential gardens

Public parks and roadside plantations

Plant Survey and Identification

Field surveys were carried out during 2024-2025. Climbers and vines were recorded through direct observation. Morphological characters including growth habit, stem

characteristics, leaves, flowers, fruits, and climbing mechanisms were utilized for identification.

Botanical nomenclature was verified using Plants of the World Online (POWO) and World Flora Online . During the course of this investigation, several field visits were conducted across diverse localities in Meerut, including the Cantonment area, the Chaudhary Charan Singh University (CCSU) campus, and various private residential colonies. To capture seasonal variations, multiple collection drafts were undertaken across different seasons. Numerous specimens of vines and climbers were collected, processed, preserved, and mounted on herbarium sheets following standard herbarium techniques. Both fresh and dried specimens were systematically identified using authoritative taxonomic literature, including Duthie's Flora of the Upper Gangetic Plain, Hooker's Flora of British India, , and Maheshwari's Flora of Delhi, as well as the DELTA (DEscription Language for TAXonomy) software. The voucher herbarium sheets are deposited and preserved in the Department of Botany, Meerut College, Meerut.

Taxonomic Classification

All species were classified according to the Angiosperm Phylogeny Group IV (APG IV) classification system (APG IV, 2016).

Compilation of Medicinal Information

Medicinal properties and phytochemical information were compiled from peer-reviewed publications indexed in Google Scholar, ethnobotanical reports, and medicinal plant databases.

RESULTS AND DISCUSSION

Species diversity- A total of 25 ornamental climber species belonging to 13 families were documented from Meerut City

Table 1.

S.No.	Botanical Name	Family (APG IV)	Common Name	Habit
1	Bougainvillea spectabilis Willd.	Nyctaginaceae	Bougainvillea	Woody climber
2	Mansoa alliacea (Lam.) A.H.Gentry	Bignoniaceae	Garlic Vine	Woody climber
3	Wisteria sinensis (Sims) Sweet	Fabaceae	Wisteria	Woody climber
4	Pyrostegia venusta (Ker Gawl.) Miers	Bignoniaceae	Flame Vine	Woody climber
5	Clerodendrum splendens G.Don	Lamiaceae	Flaming Glorybower	Shrubby climber
6	Cochliasanthus caracalla (L.) Trew	Fabaceae	Corkscrew Vine	Twining climber
7	Combretum indicum (L.) DeFilipps	Combretaceae	Rangoon Creeper	Woody climber
8	Antigonon leptopus Hook. & Arn.	Polygonaceae	Coral Vine	Herbaceous climber
9	Thunbergia mysorensis (Wight) T.Anderson	Acanthaceae	Mysore Clock Vine	Woody climber
10	Petrea volubilis L.	Petreaceae	Queen's Wreath	Woody climber
11	Clematis terniflora DC.	Ranunculaceae	Clematis	Woody climber
12	Aristolochia elegans Mast.	Aristolochiaceae	Calico Flower	Twining climber
13	Ipomoea indica (Burm.f.) Merr.	Convolvulaceae	Blue Morning Glory	Herbaceous climber
14	Mandevilla sanderi (Hemsl.) Woodson	Apocynaceae	Mandevilla	Twining climber
15	Passiflora caerulea L.	Passifloraceae	Passion Flower	Tendrill climber
16	Campsis radicans (L.) Seem.	Bignoniaceae	Trumpet Creeper	Woody climber
17	Clerodendrum thomsoniae Balf.f.	Lamiaceae	Bleeding Heart Vine	Woody climber
18	Clitoria ternatea L.	Fabaceae	Butterfly Pea	Twining climber
19	Thunbergia coccinea Wall.	Acanthaceae	Scarlet Clock Vine	Woody climber
20	Combretum rotundifolium Rich.	Combretaceae	Golden Combretum	Woody climber
21	Allamanda cathartica L.	Apocynaceae	Golden Allamanda	Shrubby climber
22	Allamanda blanchetii A.DC.	Apocynaceae	Purple Allamanda	Shrubby climber
23	Ipomoea quamoclit L.	Convolvulaceae	Cypress Vine	Annual climber
24	Thunbergia alata Bojer ex Sims	Acanthaceae	Black-eyed Susan Vine	Herbaceous climber
25	Pseudogynoxys chenopodioides (Kunth) Cabrera	Asteraceae	Mexican Flame Vine	Herbaceous climber

Family-wise Composition

Bignoniaceae was represented by four species (16%), followed by Fabaceae, Apocynaceae, and Acanthaceae with three species each (12%). The remaining families were represented by one or two species each.

Figure 1. Family-wise distribution of ornamental climbers in Meerut City

Bignoniaceae - 4 species

Fabaceae - 3 species

Apocynaceae - 3 species

Acanthaceae - 3 species

Lamiaceae - 2 species

Combretaceae - 2 species
Convolvulaceae - 2 species
Others - 6 species

Growth-form Analysis

Among the recorded species, woody climbers constituted the largest group, followed by herbaceous and twining climbers.

Figure 2. Growth-form distribution

Woody climbers - 13 species
Herbaceous climbers - 7 species
Twining climbers - 3 species
Tendrill climbers - 2 species



Medicinal Importance of Recorded Climbers

Several climbers documented in the present study possess significant medicinal value. *Clitoria ternatea* has attracted considerable attention because of its antioxidant, nootropic, antidiabetic, anti-inflammatory, and neuroprotective properties (10; 13). *Passiflora caerulea* contains γ -carboline alkaloids such as harmine and harmaline that exhibit sedative and anxiolytic effects (2). *Bougainvillea spectabilis* contains D-pinitol, a bioactive compound associated with antidiabetic activity (11). *Combretum indicum* is traditionally employed as an anthelmintic and antimicrobial plant due to the presence of quisqualic acid and related compounds (14). *Mansoa alliacea* possesses sulfur-containing compounds responsible for antimicrobial and anti-inflammatory activities (7).

Similarly, *Antigonon leptopus* and *Allamanda cathartica* exhibit antioxidant, wound-healing, and antimicrobial activities attributed to phenolics, flavonoids, and iridoid compounds (4; 12). However, *Aristolochia elegans* contains aristolochic acids, compounds known for nephrotoxic and carcinogenic effects, and therefore requires caution in medicinal applications (9).

Table 2. Medicinally important climbers and major bioactive compounds

S.No.	Botanical Name	Family	Major Medicinal Uses	Important Alkaloids / Bioactive Compounds
1	<i>Bougainvillea spectabilis</i>	Nyctaginaceae	Antidiabetic, anti-inflammatory, antimicrobial	Pinitol, betalains, flavonoids (no major alkaloid reported)
2	<i>Mansoa alliacea</i>	Bignoniaceae	Antimicrobial, antirheumatic, anti-inflammatory	Organosulfur compounds (allyl sulfides), flavonoids
3	<i>Wisteria sinensis</i>	Fabaceae	Traditional analgesic and anti-inflammatory uses	Lectins, flavonoids, saponins
4	<i>Pyrostegia venusta</i>	Bignoniaceae	Respiratory ailments, wound healing	Flavonoids, β -sitosterol, allantoin
5	<i>Clerodendrum splendens</i>	Lamiaceae	Antimicrobial, antioxidant	Clerodane diterpenoids, flavonoids
6	<i>Cochliasanthus Caracalla</i>	Fabaceae	Limited medicinal use; antioxidant potential	Phenolics, flavonoids
7	<i>Combretum indicum</i>	Combretaceae	Anthelmintic, antidiarrheal, antiparasitic	Quisqualic acid, triterpenoids
8	<i>Antigonon leptopus</i>	Polygonaceae	Antidiabetic, anti-inflammatory	Flavonoids, tannins
9	<i>Thunbergia mysorensis</i>	Acanthaceae	Limited reports; antioxidant activity	Phenolic compounds
10	<i>Petrea volubilis</i>	Petreaceae	Anti-inflammatory, febrifuge	Iridoid glycosides, flavonoids
11	<i>Clematis terniflora</i>	Ranunculaceae	Traditional treatment of rheumatism and skin disorders	Protoanemonin, saponins
12	<i>Aristolochia elegans</i>	Aristolochiaceae	Traditionally used for snakebite and inflammation (toxic)	Aristolochic acids (nephrotoxic)
13	<i>Ipomoea indica</i>	Convolvulaceae	Antioxidant, antimicrobial	Ergoline alkaloids, flavonoids
14	<i>Mandevilla sanderi</i>	Apocynaceae	Limited medicinal use	Cardiac glycosides, triterpenes
15	<i>Passiflora caerulea</i>	Passifloraceae	Sedative, anxiolytic, insomnia	Harmine, harmaline, passiflorine alkaloids
16	<i>Campsis radicans</i>	Bignoniaceae	Diuretic, wound healing	Iridoids, flavonoids

17	<i>Clerodendrum thomsoniae</i>	Lamiaceae	Antioxidant, antimicrobial	Clerodane diterpenoids
18	<i>Clitoria ternatea</i>	Fabaceae	Memory enhancer, anxiolytic, antidiabetic	Ternatins, taraxerol, flavonoids (few alkaloids)
19	<i>Thunbergia coccinea</i>	Acanthaceae	Anti-inflammatory, antioxidant	Phenolics, flavonoids
20	<i>Combretum rotundifolium</i>	Combretaceae	Antimicrobial, antioxidant	Triterpenoids, flavonoids
21	<i>Allamanda cathartica</i>	Apocynaceae	Cathartic, antimicrobial	Allamandin, iridoid lactones
22	<i>Allamanda blanchetii</i>	Apocynaceae	Antimicrobial, wound healing	Iridoids, flavonoids
23	<i>Ipomoea quamoclit</i>	Convolvulaceae	Antipyretic, anti-inflammatory	Ergoline alkaloids, flavonoids
24	<i>Thunbergia alata</i>	Acanthaceae	Antioxidant, antimicrobial	Phenolics, flavonoids
25	<i>Pseudogynoxys chenopodioides</i>	Asteraceae	Anti-inflammatory, antioxidant	Pyrrolizidine alkaloids (reported in some populations), flavonoids

The predominance of medicinally important species within the urban flora emphasizes the importance of maintaining and conserving ornamental plant diversity. Institutional campuses and public gardens serve as valuable reservoirs of these species and contribute to urban biodiversity conservation.

CONCLUSION

The present study documents 25 species of ornamental climbers belonging to 13 families from Meerut City, Uttar Pradesh. The family Bignoniaceae emerged as the dominant family, followed by Fabaceae, Apocynaceae, and Acanthaceae. Several recorded species possess important medicinal properties and contain bioactive compounds of pharmacological significance. The findings demonstrate that urban landscapes of Meerut support a rich diversity of climbers that contribute not only to aesthetic enhancement but also to biodiversity conservation and ethnomedicinal knowledge. The study provides baseline information for future taxonomic, ecological, horticultural, and pharmacological investigations in the region.

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PLANT RECOMBINASES RAD51 AND DMC1: CENTRAL PLAYERS IN GENOME STABILITY AND STRESS RESPONSE

Everest Shiwach¹, Sandeep Kumar², Punjab Singh Malik³ and Rama Kant⁴

¹Department of Botany, Deva Nagri College, Meerut, UP-250001, India

^{2,3}Department of Botany, Meerut College, Meerut, UP-250001, India

⁴Department of Botany, CCS University, Meerut, UP-250001, India

*Corresponding Author E-mail—sandeep.kumar@mcm.ac.in, ramakant.algae@gmail.com

ABSTRACT

Maintenance of genome integrity is essential for plant growth, reproduction, and adaptation to environmental stresses. DNA damage caused by endogenous metabolic processes and environmental factors such as ultraviolet radiation, drought, salinity, and temperature extremes can threaten genomic stability. Homologous recombination (HR) represents one of the most accurate mechanisms for repairing DNA double-strand breaks (DSBs), and two evolutionarily conserved recombinases, RAD51 and DMC1, play central roles in this pathway. RAD51 functions in both mitotic and meiotic cells, whereas DMC1 is predominantly meiosis-specific. Together, these proteins facilitate homology search, strand invasion and DNA repair, ensuring genome stability and proper chromosome segregation. Recent studies have highlighted their importance not only in DNA repair but also in plant responses to abiotic and biotic stresses. This mini-review summarizes the structure, function, and regulation of RAD51 and DMC1 in plants and discusses their significance in genome maintenance, stress tolerance, and crop improvement.

Keywords: RAD51, DMC1, homologous recombination, genome stability, DNA repair, stress response, meiosis

INTRODUCTION

Plants are constantly exposed to environmental challenges that induce DNA damage, including ultraviolet (UV) radiation, reactive oxygen species (ROS), drought, salinity, heavy metals, and pathogen attack. Among various forms of DNA damage, double-strand breaks (DSBs) are particularly deleterious because they can lead to chromosomal rearrangements, mutations, or cell death if left unrepaired (12).

Homologous recombination (HR) is a highly conserved DNA repair mechanism that accurately repairs DSBs using homologous DNA sequences as templates. Central to HR are the RecA-family recombinases RAD51 and DMC1, which catalyze strand exchange reactions during DNA repair and meiotic recombination (6). While RAD51 is active in both somatic and meiotic tissues, DMC1 is primarily expressed during meiosis and promotes homologous chromosome pairing and crossover formation (5).

In recent years, increasing evidence has revealed that RAD51 and DMC1 contribute significantly to plant adaptation under environmental stress conditions. Their roles extend beyond DNA repair to include maintenance of genomic integrity under adverse conditions and facilitation of evolutionary adaptation.

Homologous Recombination Pathway in Plants

The HR pathway is initiated when DNA double-strand breaks are generated either spontaneously or through external stress factors. The repair process involves several sequential steps:

1. Detection of DNA damage.
2. Resection of DNA ends to produce 3' single-stranded DNA (ssDNA).
3. Binding of Replication Protein A (RPA) to ssDNA.
4. Replacement of RPA by RAD51 and DMC1.
5. Homology search and strand invasion.
6. Formation of displacement loops (D-loops).
7. DNA synthesis and restoration of chromosome integrity.

The MRN complex (MRE11-RAD50-NBS1), COM1, BRCA2, and RAD54 assist RAD51 and DMC1 during recombination (7). This pathway ensures high-fidelity DNA repair and prevents accumulation of mutations.

Structure and Functions of RAD51

RAD51 is the eukaryotic homolog of bacterial RecA and contains conserved ATP-binding motifs known as Walker A and Walker B domains. The protein assembles into helical nucleoprotein filaments on ssDNA and mediates homology search and strand exchange reactions (Shinohara et al., 1992).

In plants, RAD51 has been characterized

in several species including *Arabidopsis thaliana*, rice, maize, and mungbean. Loss-of-function mutants exhibit hypersensitivity to DNA-damaging agents and defects in meiotic chromosome segregation (2).

The major functions of RAD51 include:

- Repair of DNA double-strand breaks.
- Maintenance of chromosome stability.
- Replication fork protection.
- Facilitation of homologous recombination.
- Prevention of genome instability.

Studies in *Arabidopsis* have shown that RAD51 deficiency leads to chromosomal fragmentation and reduced fertility, emphasizing its critical role in genome maintenance (3).

Structure and Functions of DMC1

DMC1 (Disrupted Meiotic cDNA 1) is a meiosis-specific RecA homolog that shares substantial sequence similarity with RAD51 but performs specialized functions during meiotic recombination. DMC1 promotes interhomolog recombination, ensuring accurate chromosome pairing and crossover formation (1).

During meiosis, programmed DSBs generated by SPO11 initiate recombination. DMC1 forms nucleoprotein filaments on ssDNA and facilitates strand invasion into homologous chromosomes rather than sister chromatids. This bias is essential for generating genetic diversity and ensuring proper chromosome segregation (8).

Plant mutants lacking DMC1 exhibit:

- Defective homologous chromosome pairing.
- Reduced crossover frequency.
- Chromosome fragmentation.
- Male and female sterility.

Research in *Arabidopsis*, rice, and maize demonstrates that DMC1 is indispensable for normal meiosis and fertility (5).

Comparative Roles of RAD51 and DMC1

Feature	RAD51	DMC1
Expression	Mitotic and meiotic cells	Primarily meiotic
Biological role	DNA repair and genome stability	Meiotic recombination
Homology preference	Sister chromatid	Homologous chromosome
Essential for meiosis	Supportive	Critical
Stress response	Strong involvement	Indirect involvement
Evolutionary conservation	Highly conserved	Highly conserved

Although their functions overlap, DMC1 specializes in meiotic recombination while RAD51 plays broader roles in maintaining genomic integrity throughout the plant life cycle.

RAD51 and DMC1 in Genome Stability

Genome stability is fundamental for plant development and reproduction. RAD51 and DMC1 protect genomes by accurately repairing DNA lesions and preventing chromosomal abnormalities. RAD51-mediated HR repairs DSBs generated during DNA replication and environmental stress. RAD51-deficient plants accumulate DNA damage, exhibit developmental abnormalities, and show increased mutation rates (2). DMC1 contributes to genome stability by ensuring proper chromosome pairing and segregation during meiosis. Defects in DMC1 can result in aneuploidy and reduced reproductive success (8).

Together, these recombinases maintain genome integrity across generations and facilitate the preservation of genetic information.

Roles in Stress Response

Environmental stresses increase the frequency of DNA damage in plants. HR

proteins are therefore critical components of plant stress tolerance mechanisms.

Response to Oxidative Stress

Reactive oxygen species generated during drought, salinity, and pathogen attack induce DNA strand breaks. RAD51 expression is often upregulated under oxidative stress conditions, enhancing DNA repair capacity (12).

Response to UV Radiation

Ultraviolet radiation causes DNA lesions and DSBs. Plants deficient in RAD51 exhibit increased sensitivity to UV-induced damage, demonstrating its protective function (7).

Response to Drought and Salinity

Abiotic stresses trigger genomic instability through ROS accumulation. Elevated expression of HR-related genes, including RAD51, has been reported in drought-stressed plants, suggesting an adaptive mechanism for maintaining genome integrity (4).

Response to Pathogen Infection

Pathogen attack can induce DNA damage directly or indirectly through oxidative bursts. HR proteins contribute to genome protection and may participate in defense-related signaling pathways (Yao et al., 2013).

Biotechnological Applications

Understanding RAD51 and DMC1 functions has important implications for plant breeding and biotechnology.

Potential applications include:

- Improving stress tolerance through manipulation of DNA repair pathways.
- Enhancing homologous recombination efficiency in genome editing.
- Increasing meiotic recombination frequencies to accelerate crop breeding.
- Developing stress-resilient crop varieties.

Recent advances in CRISPR/Cas-mediated genome engineering have renewed interest in HR proteins because enhanced RAD51 activity can improve precise gene targeting efficiency (Puchta, 2005).

CONCLUSION

RAD51 and DMC1 are central components of the plant homologous recombination machinery. RAD51 functions broadly in DNA repair and genome maintenance, whereas DMC1 plays a specialized role in meiotic recombination. Together, they ensure genome stability, preserve fertility, and enhance plant resilience to environmental stresses. Increasing evidence suggests that manipulation of these recombinases may provide novel opportunities for crop improvement, stress tolerance, and precision breeding. Future research focusing on regulatory networks, protein interactions, and genome-editing applications will further reveal their potential in sustainable agriculture.

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