

Original Research Article

<https://doi.org/10.20546/ijcmas.2021.1002.189>

## Quality Attributes of *Curcuma longa* in response to *Populus deltoides* Tree Spacings and Nutrient Sources

Umakanta Dash\*, Bhupender Gupta, Jyotiraditya Das and Shilpa

Department of Silviculture and Agroforestry, Dr. YS Parmar University of Horticulture and  
Forestry, Nauni, Solan-173230

\*Corresponding author

### ABSTRACT

#### Keywords

*Populus deltoides*,  
*Curcuma longa*,  
Quality, Tree  
spacing, Nutrient  
sources, Curcumin

#### Article Info

Accepted:  
15 January 2021  
Available Online:  
10 February 2021

A field experiment was carried out at an experimental field of the Department of Silviculture and Agroforestry, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during the years 2019-2020, to determine the effect of tree spacings and nutrient sources on quality attributes of *C. longa*. The experiment was laid out in Factorial RBD, consisting of three main plot treatments (*P. deltoides* tree spacings i.e. S<sub>1</sub>, S<sub>2</sub>, S<sub>0</sub>) and eight sub-plot treatments (nutrient sources i.e. T<sub>1</sub> to T<sub>8</sub>) replicated thrice. Application of T<sub>3</sub> (75 % RDNF + 25 % RDN through FYM) resulted in maximum quality attributes (curcumin, oleoresin, essential oil, crude fibre content) of *C. longa*. Under tree spacings, maximum curcumin, oleoresin and essential oil content were registered under wider spacing of *P. deltoides* (S<sub>1</sub>) whereas crude fibre content was found maximum in open field (S<sub>0</sub>).

### Introduction

Turmeric (*Curcuma longa* L.) also called as “Indian saffron” is an ancient, most valuable and sacred spice crop of India where large amount of Turmeric is produced, consumed and exported. It belongs to family Zingiberaceae and is native to the Indian sub-continent and southeast Asia and grows well in temperature between 20<sup>0</sup>-30<sup>0</sup> C (Anonymous, 2017). It is mainly propagated

through rhizome with a seed rate of 20-25 q/ha sown during the month of April-May in mid-hill regions of the country (Anonymous, 2014). Indian Turmeric is considered best in the world market because of its high curcumin content i.e. 3.14 % by weight (Hembram, 2014). Curcumin the yellow colour bioactive pigment present in the rhizome was identified in 1815 which has antioxidant, anti-inflammatory, anticancer, antibacterial, antirheumatic, antidiabetic and antiviral

properties is gaining importance with ban on artificial colours in food industry. Demand growth rate of Turmeric is around 10 % pointing to future prospects of Turmeric cultivation in the country (Chanchan *et al.*, 2017). The utilization of Turmeric by humankind presumably started for its dye (curcumin) which has a rich history of usage not only truncated to colouring foods but also now in the various other textile and pharmaceutical industries. Therefore, quality or bio-chemical traits of Turmeric have a linear relationship with its marketability. *C. longa* with less crude fibre, high essential oil, curcumin, oleoresin is considered as superior which mainly depends upon the cultivar variety, shade levels and nutrient sources. A certain degree of shade has a vital role in influencing growth, yield and quality of Turmeric (Padmapriya *et al.*, 2007 and Ranawat *et al.*, 2018). Therefore, in the present study Turmeric was grown under Poplar with the application of different nutrient sources to evaluate the contribution of tree spacings and nutrient sources in enhancing the quality of Turmeric.

## Materials and Methods

The present study was conducted at an experimental field of the Department of Silviculture and Agroforestry, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during the years 2019-2020. The experiment consisted of two structural components *viz.* *P. deltoides* as woody perennial and *C. longa* as intercrop in agrisilviculture agroforestry system. It was laid out using Factorial RBD with 24 treatment combinations replicated thrice. Plots of 5 m × 4 m, 3 m × 4 m and 3 m × 1 m were prepared in between *P. deltoides* tree spacing of 6 m × 4 m and 4 m × 4 m and, in open condition, respectively, to accommodate all treatments as per treatment details mentioned below:

## Methods used for estimating quality parameters of rhizomes of *C. longa*

### Curcumin content

As per the procedure outlined by ASTA, 0.1 g of powdered Turmeric was weighed and put into a round bottomed flask. Then 30 ml of Ethanol (solvent) was added and the round bottom flask was connected with a refluxing condenser for two and half hours.

After condensation the apparatus was allowed to cool down. The residue was filtered into a volumetric flask and the volume was made 100 ml by adding Ethanol. Further, 2 ml of it was pipette out and volume was made 25 ml using Ethanol. In the end absorbance was measured using spectro-20 at a wavelength of 425 nm using alcohol as blank.

$$\text{Curcumin content (\%)} = \frac{Dv}{100} \times \text{Absorbance} \times \frac{100}{\text{Weight of sample}} \times 165$$

Where, Dv = Dilution Volume

### Oleoresin content

Ten grams of dried, powdered sample of Turmeric was weighed and put in the fitted glass column on a stand containing cotton plug. Further, the column was filled to the brim with Acetone and kept overnight. In the next morning, an empty beaker ( $W_1$ ) was weighed and the extracts were collected from the column in  $W_1$ . Then the beaker was kept in hot boiling water bath for vaporisation of acetone contents. After evaporation, the beaker ( $W_2$ ) was weighed again and oleoresin contents were calculated by using the formula below:

$$\text{Oleoresin content (\%)} = \frac{W_2 - W_1}{\text{Weight of sample}} \times 100$$

Where,  $W_2$  = weight of beaker + extract,  $W_1$  = weight of empty beaker

### Essential oil

Ten grams of dried meshed fine powdered sample of Turmeric was weighed and put in a Clevenger apparatus followed by adding of 250 ml of water. Then the apparatus was set for distillation on heater till the contents boil (at least for 45-60 minutes).

After boiling, exact quantity of essential oil collected was measured in the graduated pipette attached with the apparatus to calculate the essential oil content in rhizome by the following formula:

$$\text{Essential oil (\%)} = \frac{\text{Amount of oil collected}}{\text{Weight of sample}} \times 100$$

### Crude fibre

Residue obtained after extraction of oleoresin was used for estimation of crude fibre. Two grams of the residue was taken and digested for 30 minutes with 200 ml of 1.25 % Sulphuric acid, filtered with boiling water and then digested in 200 ml of 1.25 % Sodium hydroxide for 30 minutes. The digested material was filtered with 25 ml of 1.25 % Sulphuric acid, 30 ml of water, 15 ml of alcohol and put in an empty weighed crucible ( $W_1$ ). The crucible was put in an oven for oven drying at  $130 \pm 2^0$  C for two hours and weighed ( $W_2$ ) followed by ignition for 30 minutes at  $600 \pm 15^0$  C in a muffle furnace and weighed accurately ( $W_3$ ). The crude fibre was calculated as:

$$\text{Crude fibre (\%)} = \frac{\text{Loss in weight on ignition } (w_2 - w_1) - (w_3 - w_1)}{\text{Weight of sample}} \times 100$$

Where,  $W_1$  = Weight of empty crucible

$W_2$  = Oven dried weight of crucible + extract

$W_3$  = Final weight of crucible + extract after ignition

### Results and Discussion

It was observed that *P. deltoides* tree spacing and nutrient sources had significantly influenced the quality attributes of *C. longa* whereas the combined effect of tree spacing and nutrient sources was found insignificant (Fig. 1–5).

### Curcumin content

The main active principle of Turmeric rhizome is curcumin, a hydrophobic polyphenol belonging to the group of curcuminoids, which are natural phenols responsible for yellow colour of Turmeric (Choudhry, 2019). It is believed that curcumin is produced in leaves and is then translocated to rhizome as stated by Li *et al.*, (2011). Under tree spacings, highest curcumin content (3.48 %) was exhibited under  $S_1$  which was at par with  $S_2$  (3.40 %) and minimum (2.92 %) under  $S_0$ . Maximum curcumin content under tree canopy indicated the positive effect of shade on curcumin synthesis, translocation, and assimilation in the rhizome (Kumar *et al.*, 2018). However curcumin content decreased in open may be due to increase in weight and volume of fresh rhizome without proper corresponding synthesis of curcumin as reported by Rao *et al.*, (1975). Hossain *et al.*, (2009) also recorded maximum curcumin content under lower light intensity. Curcumin is an important quality trait of Turmeric, as economic value of Turmeric depends upon it (Aarthi *et al.*, 2018).

Among nutrient sources, in treatment  $T_3$  curcumin content was maximum (3.94 %)

which was at par with T<sub>4</sub> (3.88 %) and minimum (2.31 %) in T<sub>1</sub> which is in corroboration with results of Padmapriya *et al.*, (2004) who purported maximum curcumin content with application of 75 % inorganic Nitrogen + FYM + *Azospirillum* and Verma *et al.*, (2012) accounted 3.18 % of curcumin content by application of 75 % RDF of NPK + 10 t FYM ha<sup>-1</sup> + *Azotobacter*. Similarly, Shah and Muthuswamy (1981) reported an increasing trend of curcumin content with increase in levels of Nitrogen upto 120 kg ha<sup>-1</sup> (Table 1).

### **Oleoresin content**

Oleoresins are yellow-dark reddish brown oily fluids obtained when a spice is extracted with a hydrocarbon solvent. Under tree spacings, in treatment S<sub>1</sub> oleoresin content was highest (11.44 %) which was at par with S<sub>2</sub> (11.37 %) and minimum (9.06 %) under S<sub>0</sub>. Correspondingly, Kittur *et al.*, (2015) also purported higher oleoresin content of Turmeric at widest spacing of Bamboo in comparison to other three spacings and treeless control which substantiates complementary to our results.

Among nutrient sources, T<sub>3</sub> registered maximum oleoresin content (12.80 %) which was statistically at par with T<sub>4</sub> (12.60 %) and T<sub>5</sub> (12.10 %) while T<sub>6</sub> (11.09 %) was at par with T<sub>7</sub> (10.30 %), T<sub>8</sub> (9.98 %) and minimum (6.96 %) in T<sub>1</sub>. The results of present study connotes similar to Chandrasekhar and Hore (2019) who elucidated that oleoresin content decreased with the decreasing level of inorganic NPK i.e. 6.86 % to 6.59% with reduction of NPK from 100 - 50 % (Table 2).

### **Essential oil content**

Under tree spacings, S<sub>1</sub> exhibited highest essential oil (5.26 %) which was at par with S<sub>2</sub> (5.17 %) and lowest (4.27 %) under S<sub>0</sub>.

Similar effect of tree canopy on maximum essential oil recovery was reported by Thakur *et al.*, (2009) who observed maximum oil recovery from *Ocimum sanctum* grown under *Morus alba* in comparison to treeless control. This was presumably due to enhanced soil properties under agroforestry system and positive effects of shade on biosynthesis of secondary metabolites as reported by Suvera *et al.*, (2015). Further, Sarangi *et al.*, (2007) elucidated that Turmeric grown under the shade of *Cinnamomum camphora*, *Cunninghamia lanceolata* and *Mesua ferrea* recorded highest curcumin, essential oil and oleoresin contents in rhizomes.

Among nutrient sources, T<sub>3</sub> registered maximum essential oil (6.17 %) which was statistically at par with T<sub>4</sub> (6.06) and minimum (2.90 %) in T<sub>1</sub>. Montemurro (2009) reported that the partial substitution of inorganic fertilizer with organic manures enhance the quality traits of field crops in comparison with sole use of inorganic fertilizer (Table 3).

### **Crude fibre content**

Crude fibre also known as weende cellulose is the insoluble remnant of an acid-alkali hydrolysis. It is the indication of the level of non digestible carbohydrate and lignin. Under tree spacings, highest crude fibre content (5.12 %) was recorded under treatment S<sub>0</sub> and minimum (4.25 %) under S<sub>2</sub>.

Similarly, Jaswal *et al.*, (1993) purported maximum crude fibre content in sole cropping and observed a decreasing trend with decrease in *P. deltoides* tree spacing which corroborates our findings.

Among nutrient sources, T<sub>3</sub> registered maximum crude fibre content (5.91 %) which was at par with T<sub>4</sub> (5.66 %) and minimum (3.15 %) in T<sub>1</sub> (Table 4–6).

**Table.1** Main plot treatments (*P. deltooides* tree spacing)

<b>S<sub>1</sub></b>	:	<b>6 × 4 m</b>
<b>S<sub>2</sub></b>	:	<b>4 × 4 m</b>
<b>S<sub>0</sub></b>	:	<b>Open field (control)</b>

**Table.2** Sub plot treatments (Nutrient sources)

<b>T<sub>1</sub></b>	:	<b>Control (No FYM or other fertilizer)</b>
<b>T<sub>2</sub></b>	:	100 % RDNF
<b>T<sub>3</sub></b>	:	75 % RDNF + 25 % RDN through FYM
<b>T<sub>4</sub></b>	:	50 % RDNF + 50 % RDN through FYM
<b>T<sub>5</sub></b>	:	25 % RDNF + 75 % RDN through FYM
<b>T<sub>6</sub></b>	:	100 % RDN through FYM
<b>T<sub>7</sub></b>	:	100 % RDN through VC
<b>T<sub>8</sub></b>	:	Jeevamrut (10 %)
❖		<b>RDNF (Recommended dose of Nitrogen fertilizer)</b>
❖		<b>RDN (Recommended dose of Nitrogen)</b>
❖		<b>Recommended dose of fertilizer for <i>C. longa</i>: NPK (30:29:60 kg ha<sup>-1</sup>)</b>
❖		<b>The recommended doses of Phosphorus and Potassium fertilisers were same in treatments T<sub>2</sub> to T<sub>5</sub>.</b>
❖		<b>The amount of FYM and Vermicompost in different treatments was quantified on the basis of Nitrogen equivalence.</b>
❖		<b>In treatments T<sub>2</sub> to T<sub>7</sub> full dose of FYM, VC, SSP, MOP and ½ dose of Urea was applied at the time of planting of rhizomes, the rest of Urea dose was applied in 2 splits i.e. 60 and 120 days after sowing.</b>
❖		<b>In T<sub>8</sub> Jeevamrut @ 10% was applied at 15 days interval after initiation of rhizome sprouting.</b>

**Table.3** Effect of *P. deltooides* trees spacing (S) and nutrient sources (T) on curcumin content (%) in *C. longa*

NUTRIENT SOURCES	<i>P. deltooides</i> tree spacing			Mean
	<b>S<sub>1</sub></b> <b>(6 × 4 m)</b>	<b>S<sub>2</sub></b> <b>(4 × 4 m)</b>	<b>S<sub>0</sub></b> <b>(Open)</b>	
<b>T<sub>1</sub> : Control</b>	2.59	2.57	1.77	2.31
<b>T<sub>2</sub> : 100 % RDNF</b>	3.10	2.93	2.21	2.75
<b>T<sub>3</sub> : 75 % RDNF + 25 % RDN through FYM</b>	4.03	4.02	3.78	3.94
<b>T<sub>4</sub> : 50 % RDNF + 50 % RDN through FYM</b>	4.01	3.99	3.64	3.88
<b>T<sub>5</sub> : 25 % RDNF + 75 % RDN through FYM</b>	3.82	3.75	3.27	3.62
<b>T<sub>6</sub> : 100 % RDN through FYM</b>	3.78	3.57	3.22	3.52
<b>T<sub>7</sub> : 100 % RDN through VC</b>	3.33	3.32	2.92	3.19
<b>T<sub>8</sub> : Jeevamrut (10 %)</b>	3.16	3.07	2.56	2.93
<b>Mean</b>	3.48	3.40	2.92	
<b>CD<sub>0.05</sub></b>				
<b>S</b>	<b>0.14</b>			
<b>T</b>	<b>0.23</b>			
<b>S × T</b>	<b>NS</b>			

**Table.4** Effect of *P. deltooides* trees spacing (S) and nutrient sources (T) on oleoresin content (%) in *C. longa*

NUTRIENT SOURCES	<i>P. deltooides</i> tree spacing			Mean
	S <sub>1</sub> (6 × 4 m)	S <sub>2</sub> (4 × 4 m)	S <sub>0</sub> (Open)	
T <sub>1</sub> : Control	7.68	7.31	5.89	6.96
T <sub>2</sub> : 100 % RDNF	10.07	9.54	7.86	9.16
T <sub>3</sub> : 75 % RDNF + 25 % RDN through FYM	13.86	13.65	10.89	12.80
T <sub>4</sub> : 50 % RDNF + 50 % RDN through FYM	13.70	13.47	10.64	12.60
T <sub>5</sub> : 25 % RDNF + 75 % RDN through FYM	13.30	12.90	10.09	12.10
T <sub>6</sub> : 100 % RDN through FYM	12.31	11.85	9.10	11.09
T <sub>7</sub> : 100 % RDN through VC	9.31	12.03	9.57	10.30
T <sub>8</sub> : Jeevamrut (10 %)	11.27	10.24	8.44	9.98
Mean	11.44	11.37	9.06	
CD <sub>0.05</sub>				
S	0.76			
T	1.24			
S × T	NS			

**Table.5** Effect of *P. deltooides* trees spacing (S) and nutrient sources (T) on essential content (%) in *C. longa*

NUTRIENT SOURCES	<i>P. deltooides</i> tree spacing			Mean
	S <sub>1</sub> (6 × 4 m)	S <sub>2</sub> (4 × 4 m)	S <sub>0</sub> (Open)	
T <sub>1</sub> : Control	3.14	3.10	2.45	2.90
T <sub>2</sub> : 100 % RDNF	4.02	4.00	3.26	3.76
T <sub>3</sub> : 75 % RDNF + 25 % RDN through FYM	6.58	6.40	5.53	6.17
T <sub>4</sub> : 50 % RDNF + 50 % RDN through FYM	6.41	6.39	5.38	6.06
T <sub>5</sub> : 25 % RDNF + 75 % RDN through FYM	6.08	6.01	5.13	5.74
T <sub>6</sub> : 100 % RDN through FYM	5.89	5.70	4.52	5.37
T <sub>7</sub> : 100 % RDN through VC	5.56	5.48	4.18	5.07
T <sub>8</sub> : Jeevamrut (10 %)	4.38	4.25	3.73	4.12
Mean	5.26	5.17	4.27	
CD <sub>0.05</sub>				
S	0.15			
T	0.25			
S × T	NS			

**Table.6** Effect of *P. deltooides* trees spacing (S) and nutrient sources (T) on crude fibre (%) in *C. longa*

NUTRIENT SOURCES	<i>P. deltooides</i> tree spacing			Mean
	S <sub>1</sub> (6 × 4 m)	S <sub>2</sub> (4 × 4 m)	S <sub>0</sub> (Open)	
T <sub>1</sub> : Control	3.05	2.96	3.45	3.15
T <sub>2</sub> : 100 % RDNF	3.44	3.18	4.64	3.75
T <sub>3</sub> : 75 % RDNF + 25 % RDN through FYM	5.93	5.77	6.03	5.91
T <sub>4</sub> : 50 % RDNF + 50 % RDN through FYM	5.72	5.38	5.88	5.66
T <sub>5</sub> : 25 % RDNF + 75 % RDN through FYM	5.40	5.11	5.61	5.37
T <sub>6</sub> : 100 % RDN through FYM	4.74	4.46	5.49	4.90
T <sub>7</sub> : 100 % RDN through VC	4.25	3.97	5.23	4.48
T <sub>8</sub> : Jeevamrut (10 %)	3.38	3.19	4.59	3.72
Mean	4.49	4.25	5.12	
<b>CD<sub>0.05</sub></b>				
S	0.24			
T	0.38			
S × T	NS			

**Fig.1** *P. deltooides* - *C. longa* agrisilviculture system



**Fig.2** Curcumin extract in ethanol



**Fig.3** Absorbance of the curcumin extract using Spectro-20 D



**Fig.4** Estimation of oleoresin content in *C. longa*



Fig.5 Clevenger's apparatus for extraction of essential oil



From the present study, it is concluded that in *P. deltoides-C.longa* agrisilviculture system espousal of treatment T<sub>3</sub> (75 % RDNF + 25 % RDN through FYM) in wider spacing of Poplar trees is insinuated as a quality enhancing nutrient module.

## References

- Aarathi S, Suresh J and Prasath D. 2018. Variability and association analysis of curcumin content with yield components in turmeric. *Electronic Journal of Plant Breeding* 9:295-303.
- Anonymous. 2014. Package of Practises for Vegetable Crops. Directorate of Extension Education, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) pp. 52-53.
- Anonymous. 2017. Spices Board India, Calicut, Kerala.
- ASTA. 1997. *Official Analytical Methods*. 4<sup>th</sup> ed. American Spice Trade Association, Washington DC. 50p.
- Chanchan M, Ghosh DK, Hore JK and Anitha M. 2017. Studies on response of manures and biofertilizers on growth and yield of turmeric (*Curcuma longa* L.). *Journal of Crop and Weed* 13:112-115.
- Chandrasekhar G and Hore JK. 2019. Yield and quality of ginger as influenced by biofertilizers, organic and inorganic manures. *International Journal of Current Microbiology and Applied Sciences* 8:968-972.
- Choudhry D. 2019. Study on the nutrient composition of local variety of turmeric (*Curcuma longa*). *The Pharma Innovation Journal* 8:205-207.
- Hembram J. 2014. *Production potential of turmeric under different cultural practices in guava based agrihorticulture practice of agroforestry*. M.Sc. Thesis. Department of Forestry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (MP). 75p.
- Hossain MA, Akamine H, Ishimine Y, Teruya R, Aniya Y and Yamawaki K. 2009. Effects of relative light intensity on the growth, yield and curcumin content of turmeric (*Curcuma longa* L.) in Okinawa, Japan. *Plant Production Science* 12:29-36.
- Jaswal SC, Mishra VK and Verma KS. 1993. Intercropping ginger and turmeric with poplar (*Populus deltoides* 'G-3' Marsh). *Agroforestry Systems* 22:111-117.
- Kittur BH, Sudhakara K, Kumar BM, Kunhamu TK, Sureshkumar P. 2015. Bamboo based agroforestry systems in Kerala, India: performance of turmeric (*Curcuma longa* L.) in the subcanopy of differentially spaced seven year-old

- bamboo stand. *Agroforestry systems* 90:237-250.
- Kumar A, Tewari S, Rawat I, Pandey R, Kumar D and Anand R. 2018. Effect of nutrient sources on growth, yield and quality of turmeric under harad (*Terminalia chebula*) based agroforestry system. *Indian Journal of Agroforestry* 20:1-6.
- Li S, Yuan W, Deng G, Wang P, Yang P and Aggarwal BB. 2011. Chemical composition and product quality control of turmeric (*Curcuma longa* L.). *Pharmaceutical Crops* 2:28-54.
- Montemurro F. 2009. Different nitrogen fertilization sources, soil tillage, and crop rotations in winter wheat: effect on yield, quality, and nitrogen utilization. *Journal of Plant Nutrition* 32:1-18.
- Padmapriya S, Chezhiyan N and Sathiyamurthy VN. 2007. Effect of shade and integrated nutrient management on biochemical constituents of turmeric (*Curcuma longa* L.) *Journal of Horticultural sciences* 2:123-129.
- Padmapriya S. 2004. *Studies on effect of shade, inorganic, organic and bio fertilizers on growth, yield and quality of turmeric (Curcuma longa L.) genotype CL 147*. Ph.D. Thesis. Department of Spices and Plantation Crops, Horticultural College And Research Institute Tamil Nadu Agricultural University, Coimbatore. 285p.
- Ranawat S, Pandey SBS, Singh J, Nayak D and Pushpanjali. 2018. Doubling the farmer's income through intercropping turmeric (*Curcuma longa* L.) under mandarin based agroforestry system in South- Eastern Rajasthan. *Journal of Pharmacognosy and Phytochemistry* 7:2560-2563.
- Rao RM, Reddy RCK and Subbarayudu N. 1975. Promising turmeric types of Andhra Pradesh. *Indian Spices* 12:2-5.
- Saranghi SK, Singh KA and Singh R. 2007. Performance of Turmeric (*Curcuma longa*) under shade of tree species. *Range Management and Agroforestry* 28:44-46.
- Shah HA and Muthuswamy S. 1981. Studies on the influence of N on the yield and yield components of turmeric. *Indian Cocoa, Arecanut and Spices Journal* 5:9-10.
- Suvera AKH, Thakur NS and Jha SK. 2015. Herbage and essential oil yield of *Ocimum* spp. intercropped under *Pongamia pinnata* based silvimedical systems in Gujarat, India. *The Bioscan* 10:81-85.
- Thakur NS, Verma KS and Rana RC. 2009. Effect of tree-crop combinations and nitrogen levels on fresh herbage and oil yield of sacred basil (*Ocimum sanctum*) grown in agrihorti-silvi-pasture system in mid hill Himalayas. *Indian Perfumer* 53:39-44.
- Verma P, Singh R and Parmar AS. 2012. Influence of integrated nutrient management on yield and curcumin content of turmeric. *A Journal of Multidisciplinary Advance Research* 1:33-38.

#### **How to cite this article:**

Umakanta Dash, Bhupender Gupta, Jyotiraditya Das and Shilpa. 2021. Quality Attributes of *Curcuma longa* in response to *Populus deltoides* Tree Spacings and Nutrient Sources. *Int.J.Curr.Microbiol.App.Sci.* 10(02): 1589-1598.  
doi: <https://doi.org/10.20546/ijcmas.2021.1002.189>