Differential effect of soil and environment on metabolic expression of turmeric 
(*Curcuma longa* cv. Roma)

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*Curcuma longa* (Zingiberaceae) is known for its uses in medicine, cosmetics, food flavouring and textile industries. The secondary metabolites of turmeric like essential oil, oleoresin and curcumin are important for its multipurpose uses. These traits of turmeric vary from place to place due to the influence of environment, soil and agro-climatic conditions. Here, we analyzed turmeric from different agroclimatic regions for influence of various factors on its growth and yield of important phytochemicals. A high curcumin yielding cultivar *i.e.*, Roma was collected from high altitude research station, Koraput (HARS) and planted in nine agroclimatic regions of Odisha. Analysis of soil texture, pH, organic carbon, micro and macro nutrients were done from all the studied zones up to 2nd generation. Plants grown in their released station *i.e.*, Eastern Ghat High Land showed 5% of curcumin and were taken as control. Plants grown in different agroclimatic zones showed a range of 1.4-5% of curcumin and 0.3-0.7% of rhizome essential oil and 0.3-1% of leaf essential oil content. Gas chromatography and mass spectra analysis showed tumerone and alpha phellandrene as the major compounds in all the zones with 10-20% variation. The present study will be immensely helpful for standardization and management of environmental and ecological factors for high phytochemical yield in turmeric plant.

**Keywords:** Curcumin, Eastern Ghats, Essential oil, Tumerone

Turmeric (*Curcuma longa* L., Fam. Zingiberaceae) is a perennial plant regarded as the golden spice, is mostly cultivated in Southeast Asia and Latin America including China, Haiti, India, Jamaica, Pakistan, Peru, Taiwan and Thailand. The secondary metabolites of turmeric such as essential oil, oleoresin and curcumin are important for its multipurpose uses. The rhizome of turmeric has been used extensively in cooking, medicine, cosmetics, and fabric dying for more than 2000 years. Essential oils of turmeric possess antimicrobial properties and wound healing properties. Curcuminoids are polyphenols responsible for the turmeric colour, yellow. Curcumin, the principal curcuminoid of turmeric, has potent antiinflammatory, anticarcinogenic, antimalarial and antioxidant properties. Its use in treating Alzheimer disease has increased its demand to many folds. Besides curcumin, the essential oils present in its rhizome and leaves, contain medicinally important phytoconstituents *viz.* α- and β-phellandrene, tumerone and terpeneol, etc. The turmeric oleoresin has hypoglycemic and paracitidal and larvicidal effects.

India is the largest producer, consumer and exporter of turmeric and is rated high in the world market for its curcumin content. The important turmeric growing states in India are, Andhra Pradesh, Karnataka, Kerala, Odisha, Maharashtra, Tamil Nadu and West Bengal in which Andhra Pradesh occupies 40 % of the total turmeric area followed by Odisha and Tamil Nadu occupying 17 and 13 %, respectively. In terms of production, Andhra Pradesh accounts 60 % of total turmeric production in India followed by Tamil Nadu (13 %) and Odisha (12 %).

A wide range of environmental and edaphic factors such as rainfall, temperature, humidity and soil nutrient, etc. are known to influence the production of plant secondary metabolites. Variation in environmental and soil nutrients and agroclimatic conditions in different zones results in varied curcumin and essential oil yield and content. Thus, variation in secondary metabolites with respect to different environmental condition plays a critical role for their increasing export potential in international market. However, studies on this issue are confined to a few genotypes.

Though many high yielding turmeric varieties have been released in India, it is confined only to particular
Materials and Methods

Rhizome collection and plantation at different agroclimatic zones—Roma is a high yielding turmeric variety released from ICAR-High Altitude Research Station (HARS) Pottangi, Odisha. Roma rhizome samples were collected from here during March-April (2011-2012) and were planted at 9 agro-climatic zones of Odisha. Fifty plants were maintained and field experiments were conducted across all 9 zones for analysis of rhizome yield, essential oil and curcumin content up to 3 consecutive years.

Soil sample analysis—The soil samples were collected from all the 9 selected zones in triplicates. Organic carbon content was determined by Wet digestion procedure of Walkley and Black; available nitrogen was determined by alkaline K2MnO4 method; available potassium, estimated by atomic flame photometer on NH4OAc digestion; and Phosphorous content by Perchloric acid digestion.

Extraction of essential oil—The essential oil from the leaves and rhizomes samples were extracted by hydro distillation using Clevenger’s apparatus. Collected samples were cleaned and sliced into pieces and 100 g of the samples were kept in the flask, heated to 60-80 °C for 6-10 h for rhizome and 4-5 h for leaves. Condensed vapour was separated through a separator attached to the flask. The oil present at the upper layer was carefully collected and percentage of oil was calculated as follows:

\[
\text{Percentage of oil} = \frac{\text{Amount of oil collected (ml)}}{\text{Weight of the sample taken}} \times 100
\]

Estimation of curcumin—Collected rhizome was cleaned with water, cut into fine pieces, allowed to dry for 4-5 days in minimum light and powdered. About 0.1 gm powder was taken into a flask to which 270 ml of acetone was added. The solution was refluxed for 8 cycles in a Soxhlet apparatus after which 250 µl of the solution was taken and diluted with acetone. The absorbance of the diluted sample was measured in a spectrophotometer at a wavelength range of 400-600 nm. Standard ASTA method was followed to estimate curcumin.

GC-MS analysis of rhizome and leaf oil—GC and GC-MS analysis of leaf and rhizome essential oil were done up to 3 years for each agroclimatic zones. The component identification was achieved by the GC-MS analysis using HP 6890 series GC (Hewlett-Packard, USA) coupled with a mass selective detector (MSD), HP 5973 series (Hewlett-Packard). The sample was injected in splitless mode in a column HP5 phenyle methyl siloxane (25 µm (film thickness) × 320 µm (internal diameter) × 30 m (length of column)). Helium was used as a carrier gas. Mass spectra were acquired over a 40-400 atomic mass unit range. Temperature programming was: initial temperature 60 °C, ramping rate 3 °C, and final temperature 243 °C, run time 61 min. Compounds were identified by comparing the mass spectral data with those in the NIST library.

Results

Effect of soil nutrients—Nutrient analysis [soil nitrogen (N), phosphorous (P), potassium (K) and organic carbon (OC) content] of the collected soil samples was done in triplicates. The soil N, P, K varied in all the 9 agroclimatic zones. Organic carbon ranged from 0.4-3.6%; Nitrogen, 112-272 kg/ha; P, 44-353 kg/ha; and K, 309-2372 kg/ha. The altitude chosen for all the agroclimatic zones ranged from a minimum of 36 m (Mid Central Table Land) to a maximum of 870 m (Eastern Ghat High Land). With increased OC, curcumin content was also increasing. However, further increase in OC i.e., 3.668 (North Central Plateau) in the soil had less curcumin content. Soil nitrogen content varied from 112-272 kg/h at Eastern Ghat High Land and North Central Plateau. Similarly, the P and K content varied from 44-353 kg/h and 309-2372 kg/h, respectively covering all the agroclimatic zones (Table 1). Effect of soil P was negligible for curcumin and essential oil content where as soil K played a critical role. With the increase in K up to 388 kg/h curcumin content increased to 5%; but further increase in K decreased curcumin content. The rhizome and leaf oil content were independent of soil N, P, K and OC content (Table 2).

Effect of environment—Environmental factors recorded from all the selected agroclimatic zones revealed wide range of temperature, rainfall and humidity (Table 1). Maximum temperature range was 34-47 °C and minimum, 5-18 °C. Humidity varied from 79-85 (maximum) and 54-60 (minimum). Average rainfall varied from 270-490 mm. Rhizome yield was maximum (405 and 415 g/plant). Effect of
environmental factors like rainfall, humidity and temperature on curcumin and essential oil was not clearly marked but high and low altitude is suitable for curcumin and rhizome production.

Analysis of phytoconstituents—The rhizome yield from all the 9 agroclimatic zones was found to be 262-415 g/plant per season. Lowest rhizome yield was recorded at Mid Central Table Land and highest was at South Eastern Ghat. Essential oil content in leaf varied between 0.37 and 1%. North Eastern Coastal Plain possessed the highest oil content of 1% and least oil was found in North Eastern Ghat which was 0.37%. Similarly, essential oil content in rhizome ranged between 0.39-0.7% where the highest and lowest rhizome oil was found at South Eastern Ghat and Mid Central Table Land, respectively (Table 2). The curcumin content too varied (1.4-5%) in all the zones; highest in South Eastern Ghat and Eastern Ghat high land. The lowest curcumin content was found in the North Central Plateau region. The releasing station of Roma was Eastern Ghat high land where the rhizome yield was 405 g/plant.

GC-MS analysis of leaf and rhizome oil—The GC-MS analysis of leaf essential oil revealed α-phellandrene, (+)-(4) carene, γ-terpinene, α-terpinolene and γ-terpinolene to be the constituents of leaf oil. α-Phellandrene was highest in North Western Plateau (82.35%) and lowest in Western Central Table Land (39%) (Table 3). Similarly, major constituents in the rhizome oil were tumerone, curlone, zingiberene, terinolene and curcumene. The tumerone content was highest in East and South East Coastal Plain (70.63%) and lowest in North Central Plateau (12.56%) (Table 4). Curlone was major
constituent in the North Eastern Coastal Plain (42.43) and North Central Plateau (44.34). Variation in major and minor constituents was observed at all the 9 zones (Table 4).

**Discussion**

**Effect of soil and environment**—Most of the released varieties of medicinal and aromatic plants always have greater productivity in their original research station. Suitable places with similar soil and environmental parameters with that of their original places are most import for their large scale cultivation\(^\text{23}\). Several researchers have studied the effect of environment on secondary metabolites reported in different plants\(^\text{24,25}\). Phytoconstituents of turmeric have been reported to vary from place to place due to influence of environment and agroclimatic conditions\(^\text{23}\). The variation in curcumin and essential oil contents in the present study has been demonstrated to be associated with the soil nutrients and environmental factors. The present observation are in alignment with earlier studies\(^\text{15,16}\) which also reported variation in rhizome yield and curcumin in different turmeric cultivars with respect to change in the environment. Anandaraj et al.\(^\text{16}\) studied genotype and environment interaction by cultivating 11 turmeric genotypes at 10 different environments. Basing upon the yield and curcumin content of all the genotypes across 10 environments they selected three stable genotypes. However, Singh et al.\(^\text{26}\) reported variation in essential oil and curcumin content of collected turmeric cultivar from different areas and selected elite turmeric genotypes on the basis of their yield and secondary metabolite production.

**Selection of suitable agroclimatic zones**—In our report, soil organic carbon (OC), N, P and K were analyzed, and both OC and K were found to significantly affect curcumin and essential oil production. High soil organic matter content uniformly supply nutrition essential for plant growth and metabolite production. Soil nitrogen forms the structural unit for many amino acids which are major precursor for metabolic biosynthesis. Nitrogen is the precursor for phenylpropanoid pathway which leads

<table>
<thead>
<tr>
<th>Zone No</th>
<th>Agroclimatic zone</th>
<th>α-Phellandrene</th>
<th>(+)-(4)-Carene</th>
<th>γ-Terpinene</th>
<th>α-Terpinolene</th>
<th>γ-Terpinolene</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>RT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>North Eastern Coastal Plain</td>
<td>4.81</td>
<td>7.49</td>
<td>6.12</td>
<td>7.0</td>
<td>7.04</td>
</tr>
<tr>
<td>2</td>
<td>Western Central Table Land</td>
<td>39.0 ± 0.04</td>
<td>2.22 ± 0.89</td>
<td>0.84 ± 0.12</td>
<td>-</td>
<td>47.4 ± 0.14</td>
</tr>
<tr>
<td>3</td>
<td>East &amp; South Eastern Coastal Plain</td>
<td>61.83 ± 0.04</td>
<td>1.86 ± 0.45</td>
<td>2.72 ± 0.16</td>
<td>12.46 ± 0.21</td>
<td>3.24 ± 0.76</td>
</tr>
<tr>
<td>4</td>
<td>North Central Plateau</td>
<td>60.2 ± 0.06</td>
<td>0.33 ± 0.12</td>
<td>5.22 ± 0.57</td>
<td>2.54 ± 0.39</td>
<td>13.28 ± 0.22</td>
</tr>
<tr>
<td>5</td>
<td>Mid Central Table Land</td>
<td>58.3 ± 0.13</td>
<td>0.87 ± 0.76</td>
<td>0.98 ± 0.34</td>
<td>16.75 ± 0.22</td>
<td>0.77 ± 0.72</td>
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<tr>
<td>6</td>
<td>North Eastern Ghat</td>
<td>64.33± 0.03</td>
<td>2.45 ± 0.34</td>
<td>1.31 ± 0.92</td>
<td>15.75 ± 0.11</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>Eastern Ghat High Land</td>
<td>56.81± 0.26</td>
<td>18.75 ± 0.14</td>
<td>2.57 ± 0.32</td>
<td>7.22 ± 0.62</td>
<td>0.22 ± 0.52</td>
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<tr>
<td>8</td>
<td>North Western Plateau</td>
<td>82.35 ± 0.13</td>
<td>4.89± 0.12</td>
<td>-</td>
<td>12.76± 0.31</td>
<td>-</td>
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<tr>
<td>9</td>
<td>South Eastern ghat</td>
<td>42.56± 0.04</td>
<td>12.38 ± 0.05</td>
<td>4.92± 0.59</td>
<td>12.15 ± 0.36</td>
<td>7.26 ± 0.42</td>
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<td>Range</td>
<td></td>
<td>39.0 – 82.35</td>
<td>0.33 – 18.75</td>
<td>0 – 5.22</td>
<td>0 – 16.75</td>
<td>0 – 47.4</td>
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<table>
<thead>
<tr>
<th>Zone No</th>
<th>Agroclimatic Zone</th>
<th>Tumerone</th>
<th>Curcumen</th>
<th>Zingiberene</th>
<th>Terpinolene</th>
<th>Curcumene</th>
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<td>RT</td>
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<tr>
<td>1</td>
<td>North Eastern Coastal Plain</td>
<td>27.58</td>
<td>28.62</td>
<td>20.65</td>
<td>6.78</td>
<td>21.23</td>
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<td>2</td>
<td>Western Central Table Land</td>
<td>64.39± 0.45</td>
<td>23.65± 0.87</td>
<td>0.22± 0.57</td>
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<td>2.45 ± 0.57</td>
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<tr>
<td>3</td>
<td>East &amp; South Eastern Coastal Plain</td>
<td>70.63 ± 0.009</td>
<td>22.81 ± 0.79</td>
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<td>-</td>
<td>-</td>
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<tr>
<td>4</td>
<td>North Central Plateau</td>
<td>12.56 ± 0.23</td>
<td>44.34 ± 0.55</td>
<td>1.23± 0.64</td>
<td>2.23 ± 1.44</td>
<td>0.89 ± 1.78</td>
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<tr>
<td>5</td>
<td>Mid Central Table Land</td>
<td>58.97 ± 0.01</td>
<td>28.01± 1.01</td>
<td>2.57 ± 0.84</td>
<td>1.98 ± 1.22</td>
<td>2.43 ± 1.02</td>
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<tr>
<td>6</td>
<td>North Eastern Ghat</td>
<td>54.56± 0.01</td>
<td>23.78± 0.87</td>
<td>3.5 ± 0.92</td>
<td>2.24 ± 1.32</td>
<td>1.37 ± 1.34</td>
</tr>
<tr>
<td>7</td>
<td>Eastern Ghat High Land</td>
<td>65.68± 0.04</td>
<td>21.74± 1.03</td>
<td>1.38 ± 0.99</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>North Western Plateau</td>
<td>46.78 ± 0.04</td>
<td>18.54± 0.32</td>
<td>1.46 ± 0.36</td>
<td>1.67 ± 1.42</td>
<td>0.99 ± 2.32</td>
</tr>
<tr>
<td>9</td>
<td>South Eastern ghat</td>
<td>33.36 ± 0.36</td>
<td>-</td>
<td>1.61± 0.45</td>
<td>1.02 ± 1.65</td>
<td>-</td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td>12.56 – 70.63</td>
<td>0 – 44.34</td>
<td>0 – 3.5</td>
<td>0 – 5.84</td>
<td>0 – 2.45</td>
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</table>
to curcumin production in turmeric. However, high N, P and K content in soil inhibited curcumin production. Thus, selection of suitable place of cultivation for a particular cultivar is essential for better production. Standardization of soil nutrients to mimic the original place of a particular cultivar should help improving the yield and metabolite production.

The present report suggests selection of suitable agroclimatic zones for large scale cultivation of turmeric cv. *Roma* on the basis of rhizome yield, essential oil and curcumin content. On the basis of rhizome yield, South Eastern Ghat, Eastern Ghat High Land East & South Eastern Coastal Plain and Western Central Table Land will be most suitable location for cultivation of turmeric cv. *Roma*. Similarly, for leaf essential oil yield, North Eastern Coastal Plain will be suitable as it showed 1% essential oil yield which is double than other regions. For rhizome oil, South Eastern Ghat and North Eastern Coastal Plain will be suitable which yielded 0.7 and 0.6% of essential oil. Further, for curcumin production, cultivation of cv. Roma will be effective in Eastern Ghat High Land and South Eastern Ghat. Thus, for rhizome yield and curcumin production Eastern Ghat High Land and South Eastern Ghat region will be most suitable.

**Conclusion**

Turmeric is widely used as spice and in medicine. Export potential of turmeric depends on its curcumin and essential oil contents. Thus, phytochemical based cultivation will be beneficial for turmeric cultivars. The present result showed that soil nutrients, environmental factors and altitude play important role in rhizome yield, essential oil and curcumin contents in turmeric. Observations of this study may be useful for selection of suitable places for cultivation of turmeric for high rhizome yield, high leaf and rhizome essential oil and curcumin production. Furthermore, the biosynthesis pathways for secondary metabolites in turmeric are a complex mechanism which is influenced by the soil and environmental factors.

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**References**