1.0. Abstract:

Turmeric or *Curcuma longa* is a perennial plant with a life cycle of nine months and native to India. It has got various and several phytochemicals and volatile oils which are anti-microbial, anti-oxidant, anti-viral, anti-inflammatory, anti-analgesic effects. Turmeric possess a biological active compound called curcumin and its derivative called curcuminoids which has anti-oxidant, anti-carcinogenic, anti-mutagenic, anti-microbial effects as reported on *in-vitro* studies and animal models. Turmeric has got a wide range of medicinal properties; despite of it has got a social, economical and traditional importance especially in India. It has been reported that turmeric can generate employment due to its high labour use and is regarded as a cash crop. It is being used as a dye, coloring agent for fabrics and also used in the form of spice to blend curry dishes.

It plays a direct or indirect role in each and every disease starting from a fever to cancer. Turmeric should be consumed daily and studies have shown that high doses of turmeric wouldn't affect or don not have any side effects on human body and is safe to use. But main drawback of this is curcumin is poorly metabolized and is excreted in form of feces so as to compensate this problem, nanoparticles are being used. There are lots of home remedies one could obtain from a dried turmeric powder and turmeric.

2. Introduction:

The name turmeric derives its name from latin word terra merrita meaning meritorious earth indicating the color of ground turmeric which has similar color of mineral pigment. Turmeric or *Curcuma longa* aka Indian saffron is an herbaceous plant belonging to *Zingiberacea* family of monocot division of kingdom Plantae. It is a perennial plant and may have originated from South-east Asia. It is believed that this species of plant was originated from North-eastern India[1]. This plant was used from our ancestral age for various purposes. Turmeric usually propagates through vegetative propagation but also it bears sexual part called flower. But it produces less viable seeds. It has an underground modified root called rhizome & through which it propagates in soil just like underground stem of *Zingiber officinale* (Ginger). It is majorly used as in dried powdered form called as spice or imparting its color, aroma and taste in any Indian food. This powder is also used to heal wounds either by applying directly on wound or taking it in milk called as "Haldi ka duudh". Turmeric contains curcumin (diferuloylmethane) as its major active ingredient, besides it contains compounds such as desmethoxycurcumin and bisdesmethoxycurcumin[2].

Fig. 1. Field Cultivation of Turmeric

Image Courtesy: (Karthikeyan, P.K., M. Ravichandran, P. Imas, and M. Assaraf.; The Effect of Potassium on the Yield and Quality of Turmeric; ***e-ifc*** No. 21; 2009.)

3.0 Morphology of Turmeric Plant:

Turmeric is a perennial monocot plant and is a native plant species of India. It has gained social, economic, medicinal and food additive in the form of spice in Indian culture.
It is a tropical plant and can be grown in sub-tropical areas. It's a rhizomatous herbaceous perennial monocot plant with 133 species of this plant know worldwide. This plant needs a temperature between 20^0C – 30^0C and also needs considerable amount of rainfall for its normal growth. Plants can grow upto 1m in height and have long and greenish oblong leaves with stem erect in posture and roots possess adventitious fibrous root system (typical in monocot plants). They possess underground modified roots called rhizomes which are harvested annually and some of it is reseeded. Rhizomes are tuberous, appear yellowish brown in color with a dull orange interior, and possess a rough and segmented scales.

The main rhizome through which secondary rhizomes arise is called as corm. This corm is actually reseeded and is pointed and tapered towards the end which possess a length of about 2.5-7.0 cm (1-3 inches) and 1 inch in diameter.
Systematic Classification :
Kingdom : Plantae
Subkingdom : Tracheobionta
Superdivision: Spermatophyta
Division : Magnoliophyta
Subclass : Zingiberidae
Order : Zingiberales
Family : Zingiberaceae
Genus : Curcuma
Species : Longa
Scientific Name: *Curcuma longa*[2].

Fig. 2. Flowering Turmeric Plant with dried rhizome and its powder:

Image Courtesy: (Jaggi Lal; Turmeric, Curcumin And Our Life: A Review; Volume-1 [7]; 2012; Page No.-11-17.)

4.0. History:

Turmeric has got wide variety of names such as in hindi “haldi”, in Sanskrit “haridra” in south India it’s called “manjal” so and it’s use came to be known 4000 years back in Vedic culture, reached China by 700 A.D., East Africa by 800 A.D., West Africa by 1200 A.D. and Jamaica by 18th century. In Sanskrit, turmeric has got around 53 names :
Anestha, Bhadra, Bahula, Dhirgharaja, Gandhpalashika, Gauri, Gharshani, Haldi, Haridra, Harita, Hemaragi, Hemaragini, Hridyavilashini, Jayanti, Jawarantika, Kanchani, Kaveri, Laxmi, Nisha, Mangalprada, Krimighni or Kaspha, Kshamata, Mangalya, Mehangi, Nishakhya, Nishawa, Patwaluka, Pavitra, Pinga, Pita, Pinja, Pitika, Rabhangavasa, Ranjani, Ratrimanika, Shifa, Shobhan, Shiva, Shyama, Soubhagaya, Survana, Survanavara, Tamasini, Umavara, Vairagi, Varavarnini, Varna datri, Varini, Vishangi, Yamini, Yoshitapriya and Yuvati.

In the times of Lord Rama turmeric was believed for worshipping the Sun during solar period of India. The first discovery of turmeric got to be known by Marco polo in 1280 AD referring it as Indian Saffron used for dying clothes. Chinese tradition used turmeric as medicinal plant mainly for spleen, stomach and liver medicines for about 1000 years. It was also used as stimulant and purifies the blood and decrease blood pressure, to clean gastric discomfort, and stagnation in men, women and children. Especially it has gained more importance to women, as it is believed as it stimulates uterus and cleans menstrual stagnation. It has also got the properties of being anti-biotic, anti-viral and analgesic[3].

Another great invention came in the year of 1870’s when chemists discovered that orange yellow root powder of turmeric turned reddish brown when treated with alkaline chemicals. This discovery led to use of turmeric paper for alkalinity. A Modern Herbal, book by Maude Greve’s states that “Turmeric is a wild aromatic stimulant seldom used in medicine except coloring. It was once cure for jaundice. It’s chief use in manufacture of curry powder. ” Research on turmeric began in Germany in early 1920’s. Sesqueterpenes, essential oil was extracted in 1926 from turmeric and ascribed as therapeutic activity[16].

5.0. Criteria to grow Turmeric Plant:

5.1. *In Vitro*:

Curcuma longa or turmeric could be grown naturally but it would take more time to grow than propagating in in-vitro. This could be achieved through plant tissue culture technique. This technique establishes production of more plantlets in short period of time (usually 2-3 months) with genetically individual, uniformly growing plants, and mainly production of disease free plants. In tissue culture techniques, presence of plant growth regulators (PGR) such as cytokinin, auxin etc. plays a vital role in determining metabolism of plant which all together determines the induction of shoot or root or both[4]. The common media which is used in micropropagtion of plants is Murashige and Skoog's (MS) media without any addition of natural supplements. Cytokinin such as 6-benzyl aminopurine (BAP) are known to induce shoots and to more specific it reduces the growth of apical shoot thereby inducing more and more axillary shoots depending upon the concentration[5].
This type of in-vitro technique further is divided into six phases :

1) Initiation,
2) Multiplication,
3) Rooting,
4) Primary Hardening,
5) Secondary Hardening and
6) Field Establishment.

5.1.1. Initiation:

5.1.1.1. Collection of Explants:

For initiation process, lower parts of shoot with meristem were selected of patented *Curcuma longa* of approximately 1-1.5 cm in length and 0.5 cm in diameter from Plant Biotechnology Department, Rajiv Gandhi Institute of I.T. and Biotechnology, Pune.

5.1.1.2. Surface Sterilization:

After removal of plant from cocopeat, surface sterilization was performed as follows:

Rinse 2-3 times by distilled water.

↓

Add 2% fungicide solution for 30 mins.

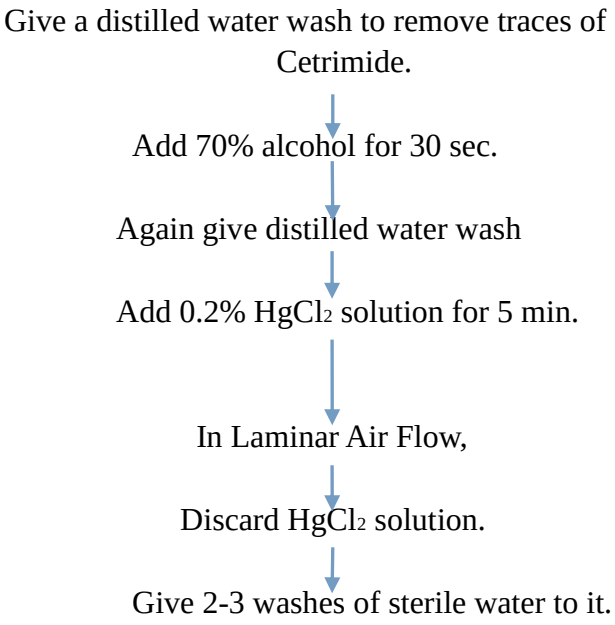
↓

Give a distilled water wash to remove traces of Fungicide.

↓

Add 2% cetrimide solution for 15 mins.

↓



5.1.1.3. Media Preparation:

Murashige and Skoog's media was used in addition of BAP 3 mg/l as a plant growth regulator was used for initiating the explants to get form into multiple shoots. This media was then, autoclaved it at 15 psi and 121^0C for 15 min. and validated for a day.

Fig.3.Composition of MS media:

Table 11.2: Composition of a typical Murashige and Skoog plant culture medium

Essential element	Concentration in stock solution (mg/l)	Concentration in medium (mg/l)
Macroelements[b]		
NH_4NO_3	33 000	1 650
KNO_3	38 000	1 900
$CaCl_2 \cdot 2H_2O$	8 800	440
$MgSO_4 \cdot 7H_2O$	7 400	370
KH_2PO_4	3 400	170
Microelements[c]		
KI	166	0.83
H_3BO_3	1 240	6.2
$MnSO_4 \cdot 4H_2O$	4 460	22.3
$ZnSO_4 \cdot 7H_2O$	1 720	8.6
$Na_2MoO_4 \cdot 2H_2O$	50	0.25
$CuSO_4 \cdot 5H_2O$	5	0.025
$CoCl_2 \cdot 6H_2O$	5	0.025
Iron source[c]		
$FeSO_4 \cdot 7H_2O$	5 560	27.8
$Na_2EDTA \cdot 2H_2O$	7 460	37.3
Organic supplement[c]		
Myoinositol	20 000	100
Nicotinic acid	100	0.5
Pyridoxine-HCl	100	0.5
Thiamine-HCl	100	0.5
Glycine	400	2
Carbon source[d]		
Sucrose	Added as solid	30 000

Image Courtesy :
(http://www.biologydiscussion.com/plants/plant-tissue-culture/plant-tissue-culture-7-things-to-know-about-plant-tissue-culture/12758)

5.1.1.4. Inoculation:

Complete the explant surface sterilization and media sterilization. Scrap the explant in laminar air flow just as to remove the part of plant which faced surface sterilization. Also cut the shoot if it's too long.

Inoculate it in vertical fashion such as meristem part of plant touches the media and above shoot portion is placed vertically upwards[15].

5.1.1.5. Establishment of Culture:

After inoculation, cultures were maintained in aseptic growth room of temperature of 25^0C in light and dark conditions. The observations were recorded and analyzed.

5.1.1.6. Observations:

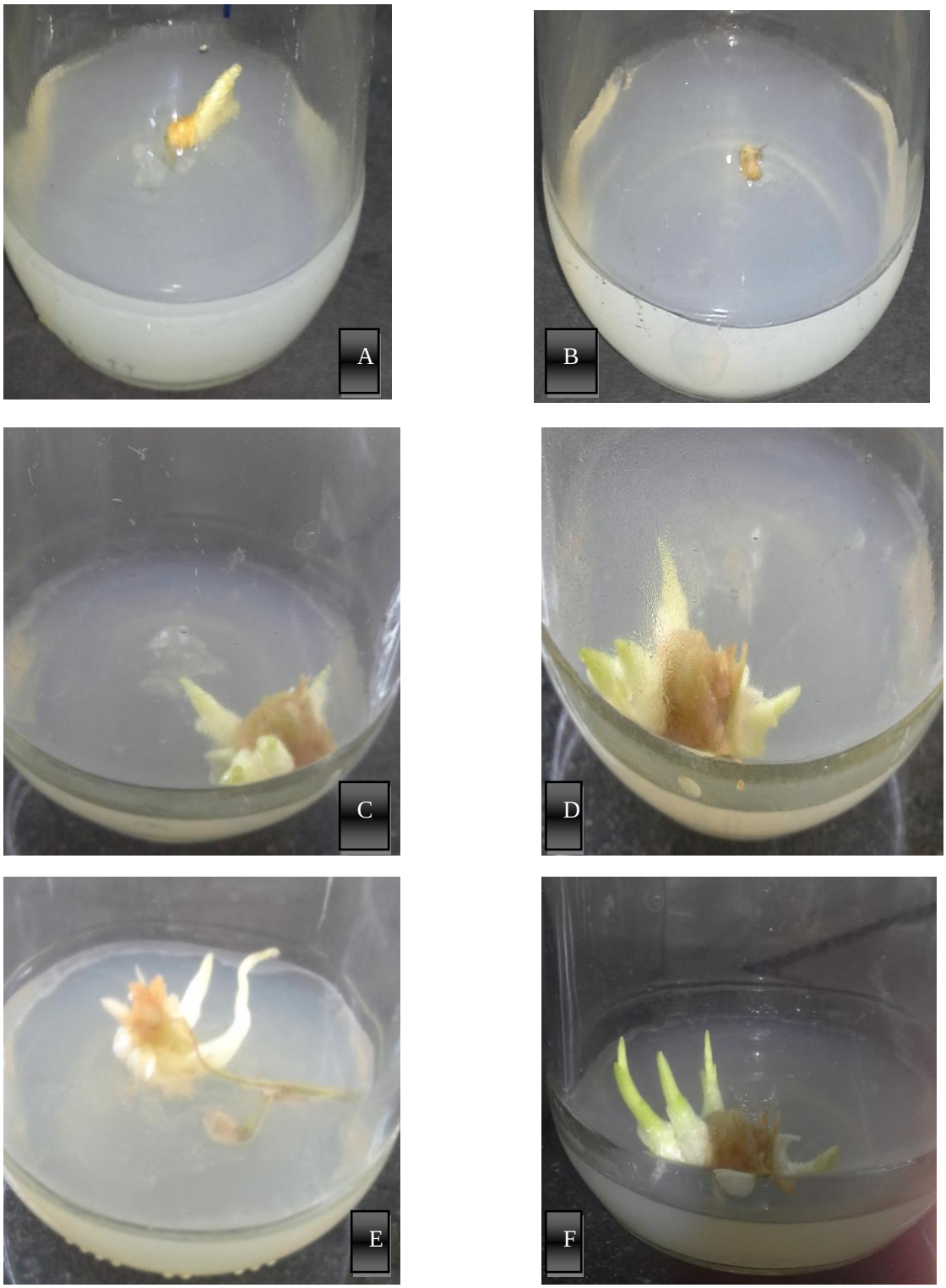
All explants were inoculated and three were kept in dark condition while three with kept in light condition of a photoperiodism of 12 hours light and 12 hours dark. Explants of dark condition showed quick growth while that of light condition. They showed quick induction of shoot first and later for root induction in first week itself. Shoot induction was also seen in light condition but root induction was delayed. Shoots now, started proliferating or elongating itself in both light as well as dark condition. Whole shoot was developed in three weeks in dark condition with a height of 3-4 cm. Light condition shoot development was occupied just 2-3 days after dark conditions and attained a height of 4-5 cm.

5.1.1.6. Conclusion:

Explant showed a rapid development of shoot and root under dark condition much better than light condition. Shoot induction, elongation was seen in both dark and light conditions. There was no significant change between light and dark condition explants except light condition explants attained slight more height than that of dark condition explants.

That means dark condition favors the growth of shoot and root initiation when supplied with BAP 3 mg/l as a PGR.

Fig.3. In-vitro Micro propagation of Turmeric:

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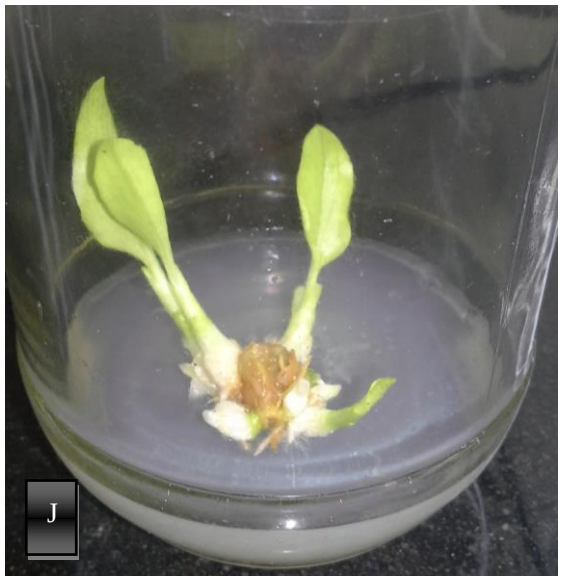
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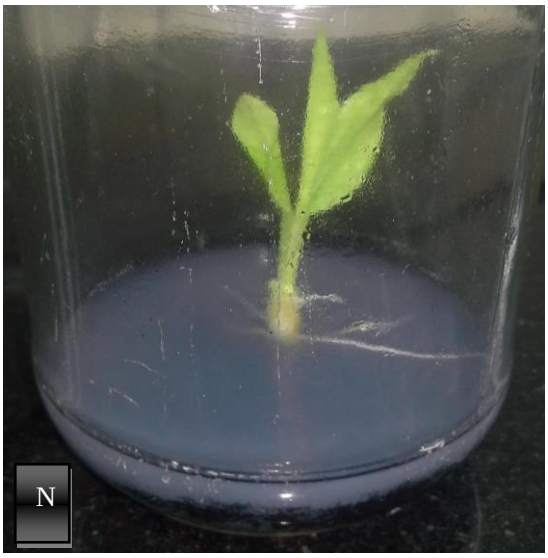
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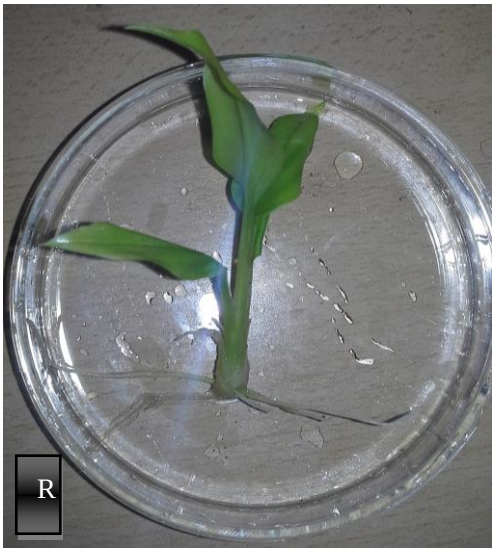
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A: Explant under dark condition showing initiation of root and shoot, B: Explant under light condition showing initiation of shoot, C: Explant under dark condition showing shoot multiplication, D: Explant under light condition showing shoot multiplication and tissue proliferation, E: Explant under dark condition showing shoot elongation, F: Explant under light condition showing shoot proper elongation and tissue proliferation and greening of shoots, G: Explant under dark condition showing shoot elongation and greening of shoots, H: Explant under light condition showing shoot elongation and greening of shoots, I: Explant under dark condition showing shoot elongation, greening of shoots and emergence of leaf, J: Explant under light condition showing shoot elongation, greening of shoots and emergence of leaves, K: Plant under dark condition showing induction of roots in rooting media, L: Plant under light condition showing induction of roots in rooting media, M: Plant under dark condition showing induction of roots in rooting media, N: Plant under light condition showing induction of roots and emergence of new leaves in rooting media, O: Plant under light condition showing root induction in color media, P: Plant under light condition showing root elongation and leaves elongation in rooting media, Q: Plants under light condition for rooting purposes but just as commercial representation, R: Plant washed with tap water and fungicide prior to primary hardening, S: Commercial production of plants showing leaves emergence, shoot and root induction, T: Plantlet in polybag showing leaf emergence and root development after two weeks.

5.1.2. Multiplication:

This phase includes the induction of many shoots from a shoot base in a short period of time. Here, media used is different as that of initiation phase but the basal (MS media) media remains same with PGR's such as BAP and Adenine Sulphate which is used for multiple shoot induction.

5.1.2.1. Media Preparation:

Media for multiplication phase is defined such that to induce more and more shoot in less period of time. Media was full strength MS media plus BAP 2 mg/L and Adenine Sulphate 2 mg/L.
It was autoclaved at 15 psi, 121^0C for 15 minutes.

5.1.2.2. Inoculation:

Explant for multiplication was obtained by slicing and cutting meristem in such a way that it resembles square shaped structure. Also, apical meristem is removed to induce multiple shoots and extra lateral meristem are sliced off for creating many explants. These explants are planted vertically to maintain its geographic affinity. These cultures were stored in aseptic growth area of temperature of 25^0C. Record the observations and analyze the conclusions from it.

5.1.2.3. Observations:

Explants were inoculated in their two type of media that is, MS media and MS plus BAP (2 mg/L) plus Adenine Sulphate (2 mg/L) and were kept in aseptic growth area of temperature of 25^0C. Three explants were kept in light conditions and three were kept in dark conditions due to scarcity of explants. Photoperiodism of light conditions was 12 hour light and 12 hour no light condition while that of dark condition was with no light exposure given to it that means 24 hours of dark conditions. After three days of incubation in dark conditions, media containing PGR that is, MS plus BAP plus Adenine Sulphate showed shoot induction. After one week 4-5 shoot induction was seen and one of culture vessel was now shifted to light condition. After 25 days of incubation in dark condition there was shoot induction but the size of shoots were irregular that means one shoot attained a height of 4-5 cm, while another shoot attained a height of 2-3 cm, as well as there was tissue proliferation in media containing PGR under dark condition. While the control showed same growth time but shoot induced were just only 2 and was kept completely in dark condition.

While that of in light conditions, shoot induction comparatively delayed than that of dark condition. One of the culture vessel after incubation after a week which was shifted to light conditions showed proper shoot induction, meristem proliferation, and production of young leaves. Explant which was shifted from dark condition after a week had induced shoots which after 2 weeks of incubation in light condition showed growth of four new shoots with approximate same shoot lengths and were found to attain a height of approximate 3..5-4.5 cm. And after 3 weeks of incubation in light condition they showed development of young leaves and simultaneous meristem proliferation was seen. While that of explant in dark condition delayed the induction of new leaves but it favored more shoot and root induction of irregular sizes.After three weeks of incubation in light condition, one of explant wasn't able to induce shoots, so it was shifted to dark condition, and after two weeks in dark condition it induced two new shoots.

5.1.2.4. Conclusion:

The growth of explants were recorded daily and analyzed that dark condition favored shoot and root induction than light condition. But proper growth of shoots was seen in light condition, so the best method to get multiple shoots is incubate the explants in dark condition for one week to induce multiple shoots. Than shift explants to light condition for proper development of shoots and tissue proliferation. It was obvious that media containing plant growth regulator would give more shoots than control media (without plant growth regulator).

There was not significant change in number of shoots produced when compared between dark and light condition explants, as each of them gave 4 new shoots with tissue proliferation, this tissue can be useful for second cycle of multiplication.

5.1.3. Rooting:

After shoots get formed, roots are also important to shift into field via hardening. Media used for hardening was MS plus 2% activated charcoal plus IAA 1 mg/L (Indole Acetic Acid). Charcoal would give essential dark environment for roots to grow and PGR IAA is needed to induce new leaves. Media was sterilized in autoclave at 15 psi, 121^0C for 20 minutes and validated for a day.

Whole shoot was used as explant for rooting, and was inoculated in upright position as to depict its natural growth. It was incubated in aseptic growth room with a temperature of 25^0C.

5.1.3.1. Observations:

Explants were incubated in aseptic growth area under light and dark conditions. It was observed that explant in light condition showed root initiation after a week in light condition. After two weeks of incubation in light condition, there was emergence of two young leaves with root elongation. After four weeks a complete plant was setup with four leaves and 5-6 roots.

While that of explant in dark condition, delayed the growth of root initiation and young leaves induction. After three weeks in dark conditions, root initiation occurred and there was induction of new shoot but it delayed the induction of new young leaves. Also the control medium that is without activated charcoal and IAA, also was found to initiate root a bit slowly than media with charcoal and IAA.

5.1.3.2. Conclusion:

Day by day analysis was recorded and was found that light condition favors the growth of root initiation and induction of young leaves. While that of dark condition, initiated the growth of root but was unable to produce leaves. And as obvious, control media also delayed the initiation of root as well as leaves. So the best choice for rooting is to incubate explant in

charcoal and IAA containing media in light condition.

5.1.4. Primary Hardening:

Hardening or acclimatization is the process of adapting in vitro plant to adapt to its natural habitat. Hardening is an essential step to accommodate the plant for field. It's an gradual process, and therefore first it should be kept in shady place and then can be transferred in sunlight. Requirements for hardening are sterilized cocopeat, MS liquid media without vitamins, poly bag, plastic cup, petri dish.
For hardening a complete plantlet with 4 leaves and some primary roots is used. This is now taken out from medium, washed it with running tap water to remove agar than with fungicide and now is planted in plastic cup containing cocopeat. Cocopeat is then filled with liquid MS media without vitamins and fungicide also. Poly bag is now applied to cover the plantlet and incubated in aseptic growth room with a temperature of 25^0C.

5.1.4.1. Observations:

Plantlet was grown in cocopeat just acting as a soil support in aseptic growth room of 25^0C in light condition. In day two there was induction of yellowing in previous leaves, while after two days later from it there was induction of new leaf. On incubation, on day 9 leaf elongation was seen and simultaneous growth of root was also seen. On day 15, there was induction of second young leaf and completed the growth of first.
After completion of three weeks whole plantlet was ready for transferring into secondary hardening process. Also there was slight elongation of plant's height, induction of new leaves and root system development was seen.

5.1.5. Secondary Hardening:

In-vitro plant has to gradually adapt its natural habitat, and therefore prior to field establishment secondary hardening is carried out. This step is utmost important as now it has to adapt in sunlight. Primary hardened plant with cocopeat is inculcated in soil. First few days of this are subjected in shady or areas having less sunlight to gradually adapt to scorching sunlight or either wise it would burn. Slowly intensity and duration of exposure to sunlight is increased and simultaneous plant attains a proper height, emergence of new leaves could be seen and there is a proper development of root system. This procedure is ended up in just three weeks and the plant then could be shifted to field.

5.1.6. Field Establishment:

It is the last step of *in-vitro* technique, now the plant has changed itself from heterotrophic to autotrophic. It has now adapted itself to grow in natural environment. Still the interaction of plant with other plants is missing which could be acquired in this process. Simultaneously, one

could obtain desired product from it.

5.2. Agro-techniques:

Turmeric is largely grown in India and mainly in tropical countries such as Bangladesh, China, Thailand, Cambodia, Malaysia, Indonesia and Philippines. In India, majorly Tamil Nadu is highest producer of turmeric with 25,000 ha of area yielding as much as 35% national requirement followed by Andhra Pradesh, Maharashtra, Orissa, Karnataka and Kerala. Turmeric could be grown in tropical and sub-tropical region, upto 1600 meters above sea level with a temperature range of 20^0-40^0C and favors rainfall region of about 1500 mm. Mainly it is sown in month of July and harvested in month of April and hence it is gets matured in nine months. Soil conditions such as well-drained, fertile, sandy, black, red or alluvial soils rich in humus and uniform in texture are the requirements for growing turmeric. Optimal growth is obtained when soils are loamy having well drainage and irrigation facilities. Turmeric can't withstand soil conditions with water stagnation or alkaline soil[2]. The crops get ready for harvesting in seven to nine months as it depends on various factors like time of sowing, temperature, soil condition, irrigation facilities, external fertilizers if added etc. Turmeric generally appears in market from month of February to month of May. Maturity of turmeric can be marked easily by just attributing to its morphology such as leaves of turmeric turns dry and are light brown and yellowish in color. Height of crop reaches upto 1.5 feet with 8-10 branches and crack development on soil indicates rhizome formation and good yield of turmeric. While ploughing, care is taken for rhizomes and are lifted with spade. Rhizomes are then cleaned from mud and extraneous matter adhering to it[6].
The harvested green rhizomes are then boiled in water, and are then let to dry in sun for 15-20 days and are stirred 3-4 times to ensure uniform drying. When drying procedure is completed, turmeric becomes hard and stiff which is then rubbed on surface of drying floor or rubbed under the feet covered with gunny cloth. Root bases are separated in winnowing procedure[2].

5.2.1. Effect of Potash on Yield and Quality of Turmeric:

Turmeric is valued for its imparting brilliant yellow color to food especially in curry, giving culinary dish a characteristic peppery taste. The active ingredient in turmeric has the ability of various biological activities such as anti-bacterial, anti-fungal, anti-parasitic, anti-mutagen, anti-inflammatory, hypolipedemic, hepatoprotective, lipoxygenase, cyclooxygenase and protease inhibitory effects. Turmeric has a high demand for mineral nutrients and yield production. The average rhizome yield of turmeric in Erode district of Tamil Nadu ranges from 3-5 mt/ha.

The field experiment was set in Arachalur, in Erode district of Tamil Nadu having inceptisol meaning a soil with little horizon development. Soil properties of Arachalur in Erode district of Tamil Nadu:

Table No. 1 Soil Properties

Physical Properties	unit	
Clay	g kg^{-1}	155
Silt	g kg^{-1}	230
Fine sand	g kg^{-1}	240
Coarse sand	g kg^{-1}	350
Texture		Sandy loam
Chemical Properties		
Soil pH (1:2)		6.5
EC	dSm^{-1}	0.05
CEC	cmole kg^{-1}	12.1
Organic carbon	g kg^{-1}	4.8
$KMnO_4$–N	mg kg^{-1}	105
Olsen –P	mg kg^{-1}	8.2
NH_4OAC–K	mg kg^{-1}	60
Exchangeable Ca	cmole kg^{-1}	7.0
Exchangeable Mg	cmole kg^{-1}	1.8

Image Courtesy: (Karthikeyan, P.K., M. Ravichandran, P. Imas, and M. Assaraf.; The Effect of Potassium on the Yield and Quality of Turmeric; ***e-ifc*** No. 21; 2009.)

The experimental design was set with a seven different treatments in a randomized block design of a plot size of 10*6 m with the site previously prepared in broad ridge and furrow for cultivation of rhizomes. Basal treatments such as farmyard manure- 25 mt/ha, P_2O_5- 50 kg/ha, and 5 kg/ha of $ZnSO_4$ and $FeSO_4$. The fertilizers potassium, nitrogen and magnesium was applied in four equal spilts such as first spilt was applied with basal treatments, and following were applied after 30, 60 and 90 days of planting. Various cultivation procedures such as irrigation, plant protection, crop growth, growth parameters such as tiller count per plant, secondary rhizomes were recorded. The plant was harvested after 290 days of planting and yield of rhizomes were recorded also rhizomes were sampled for curcumin content and various other factors.
The result were as follows[6] :

Table No. 2. Effect of Potassium on Yield and Quality on Turmeric;

Treatments	Potash application	No. of tillers	No. of secondary rhizomes	Fresh turmeric yield	Curcumin content
	kg ha^{-1}	*No./plant*	*No./plant*	*mt ha^{-1}*	*%*
K1	0 (control)	3.70	8.70	18.0	2.90
K2	40	5.70	13.3	24.3	3.30
K3	120	8.00	17.7	28.3	3.63
K4	200	10.7	20.3	31.4	3.93
K5	260	14.3	23.3	34.4	4.47
K6	260 + 60*	14.7	24.0	34.9	4.53
K7	320	11.0	20.7	32.4	4.07
CD (P=0.05)		0.80	2.09	1.68	0.15

*60 kg $MgSO_4$ ha^{-1}

Image Courtesy: (Karthikeyan, P.K., M. Ravichandran, P. Imas, and M. Assaraf.; The Effect of Potassium on the Yield and Quality of Turmeric; ***e-ifc*** No. 21; 2009.)

Fig.4. Rhizome and Tiller Count in Control (K_1) and Supplemented with Potash (K_6)

Image Courtesy: (Karthikeyan, P.K., M. Ravichandran, P. Imas, and M. Assaraf.; The Effect of Potassium on the Yield and Quality of Turmeric; ***e-ifc*** No. 21; 2009.)

6.0. Composition of Turmeric:

Turmeric contains more than 100 compounds which have been isolated individually. The main and major component is present in it's root and is a volatile oil and is named as turmerone along with curcuminoids. Curcuminoids majorly consists of curcumin, demethoxycurcumin, 5'-methoxycurcumin and dihydrocurcumin which are reported to have an antioxidative properties. It does contain moisture (>9%), Curcumin (5-6.6%), extraneous matter (>0.5% by weight), mould (<3%) and volatile oils (<3.5%). Also volatile oils also includes d-α-phellandrene, d-sabinene, cinol, borneol, zingiberene, and sesquiterpenes. Sesquiterpenes include germacrone, termerone, ar-(+)-, α-, and β-termerones, β-bisabolene, α-curcumene, zingiberene, β-sesquiphellanderene, bisaucrone, curcumenone, dehydrocurdione, procurcumadiol, bis-acumol, curcumenol, isoprocurcumenol, epiprocurcumenol, procurcumenol, zedoaronediol, and curlone and are specific for specific species. Turmeric has a typical fragrance due to compounds such as turmerone, arturmerone and zingiberene. The rhizomes of turmeric are found to contain four new polysaccharide-ukonans with stigmasterole, β-sitosterole, cholesterol and 2-hydroxymethyl anthraquinone.

Turmeric contains wide range of constituents present in it having wide range of biological activities. For instance, there are 20 at least 20 known molecules that are anti-biotic, 14 are found to be cancer preventives, 12 are anti-tumor, 12 are anti-inflammatory, while that of 10 are anti-oxidants. In count, there are total 326 biological activities of turmeric known till today. Majorly, 95% of research is done of curcuminoids extract of turmeric, though the turmeric contains only 3-5% of curcuminoids[3]. Turmeric has a high nutritional status that can be expoilted by doing qualitative and quantitative estimation. The main active ingredient of turmeric, curcumin contains many several vitamins and vitamin precursors which leads to production of vitamin C, beta-carotene as well as polyphenol coupled with fatty acid and essential oil. Melting point of curcumin ($C_2H_{52}OO_6$) is 184.2^0C and is soluble in ethanol and acetone but insoluble in water. Curcumin is known to be a potent antioxidant molecule and is the most bioactive biomolecule and possess anti-platelet, cholesterol lowering, antibacterial and antifungal effects[7].

Table No.3 Composition Of Turmeric:

Entry	Constituents	Quantity per 100g
1.	Ascorbic acid (mg)	50.0
2.	Ash (g)	6.8
3.	Calcium (g)	0.2
4.	Carbohydrate (g)	69.9
5.	Fat (g)	8.9
6.	Food energy (K Cal)	390.0
7.	Iron (g)	47.5
8.	Niacin (mg)	4.8
9.	Potassium (mg)	200.0
10.	Phosphorus (mg)	260.0
11.	Protein (g)	8.5
12.	Riboflavin (mg)	0.19
13.	Sodium (mg)	30.0
14.	Thiamine (mg)	0.09
15.	Water (g)	6.0

Image Courtesy : (Jaggi Lal; Turmeric, Curcumin And Our Life: A Review; Volume-1 [7]; 2012; Page No.-11-17.)

Fig.5. Natural Metabolites of Turmeric and Curcumin

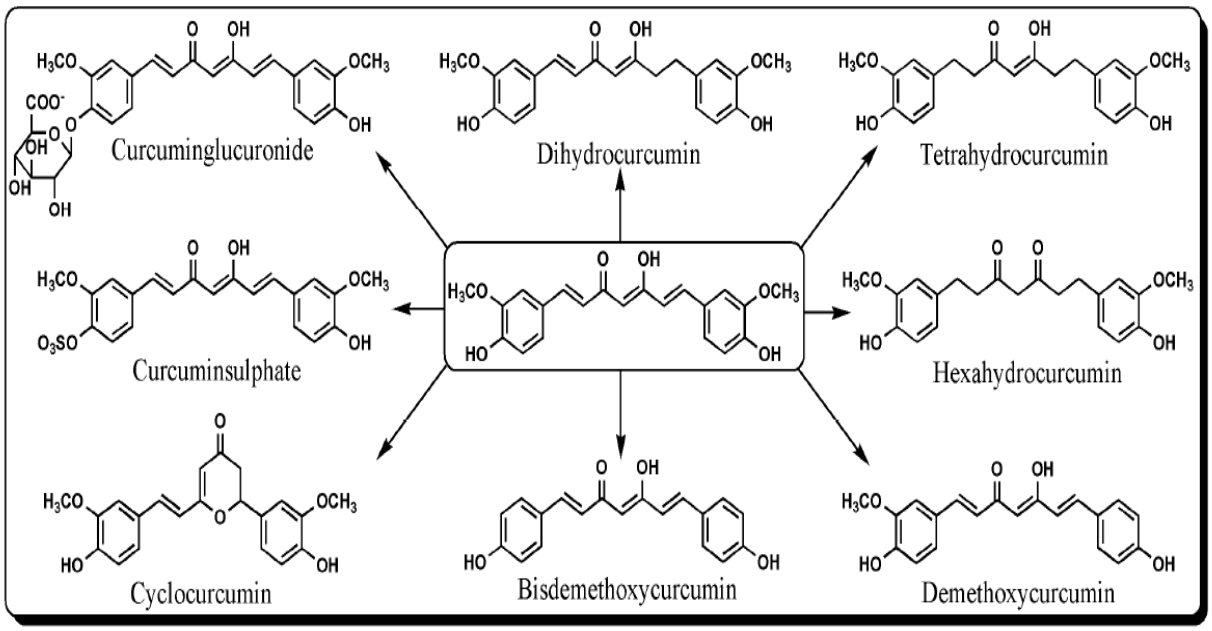

Image Courtesy : (Jaggi Lal; Turmeric, Curcumin And Our Life: A Review; Volume-1 [7]; 2012; Page No.-11-17..)

Table No.4. Phytochemicals and Volatile Oils Concentrations Present in Different Organs of Turmeric:

Entry	Component	Concentration (%)			
		Root	Rhizome	Leaf	Flower
1.	β-Bisabolene	2.3	1.3	-	0.9
2.	1,8-Cineole	0.7	2.4	6.5	4.1
3.	p-Cymene	3.3	3.0	5.9	1.6
4.	p-Cymen-8-ol	1.5	0.3	0.8	26.0
5.	Tr-Curcumin	7.0	6.3	0.2	1.9
6.	Curlone	0.6	10.6	0.2	0.3
7.	Dehydrocurcumin	4.3	2.2	Tr	-
8.	Myrcene	Tr	0.1	2.3	0.2
9.	α-Phellandrene	0.1	0.1	32.6	-
10.	β-Phellandrene	-	Tr	3.2	Tr
11.	α-Pinene	0.1	0.1	2.1	0.4
12.	β-Pinene	0.1	Tr	2.8	0.1
13.	Terpinolene	0.1	0.3	26.0	7.4
14.	Tr-Turmerone	46.8	31.1	0.1	1.2
15.	Turmerone	-	10.0	0.9	1.0
16.	Others	33.1	32.2	16.4	54.9

Tr-Trace

Image Courtesy: (Jaggi Lal; Turmeric, Curcumin And Our Life: A Review; Volume-1 [7]; 2012; Page No.-11-17.)

7.0. Safety, Efficacy and Contradictions:

Turmeric is used as spice and dye in day to day household activities for many centuries. Up to date there are no toxic effects in either animals or humans founded with the use of turmeric also even at high doses. The U.S. Food and Drug Administration or FDA conducted their own clinical trials with turmeric and published a 300 page monograph. The active or major component of turmeric, curcumin was declared as GRAS- generally regarded as safe by FDA department. Hence, thereof turmeric and its components are currently being used in cereals, mustard, chips, cheese, butter in large amounts in U.S. There was a case study reported regarding for the use of safety of turmeric oil and the clinical trials were conducted on healthy volunteers for three months. Their health was checked on regular basis, and was found that there were no side effects of turmeric oil in any volunteer when they consumed for three months and also their body weight, blood pressure, renal, hematological and hepatic toxicity was administered but turmeric oil was found to be safe[3].

8.0. Necessity to Consume Turmeric Daily:

Turmeric has been still being used in foodstuff, cosmetics and medicines since ancient times and widely used in South India and Middle Eastern cooking. It is used as coloring agent in cheese, butter and other foods and lends a distinctive yellow color flavor in curry cuisine. Due to a rising influence of Indians turmeric travelled to Ethiopian culture and in South Africa, traditionally it is used to give boiled rice a golden color. It plays a vital role in manufactured food products such as canned beverages, dairy products, bakery products, yellow cakes, orange juice, ice cream, yog hurt, biscuits, popcorns, sweets, sauces and gelatins. Commercially available curry powders do contain turmeric powder as a significant ingredient. The reported consumption of turmeric in Asian countries in humans is in the range of 200-1000 mg/day or 160-440 g/year of a person. Rural areas do consume more turmeric- 600 mg/day of person than urban areas person of 200 mg/day.

According to some estimates, as much as USD $10 billion is spent on alternative therapies every year. Out of which USDA $650 millions are spent on botanical supplements which are used for inflammatory diseases such as chronic obstructive airways disease (COPD), asthma and rheumatoid arthritis. These supplements have also been used for long centuries ago in traditional medicine such as Ayurveda, Chinese medicine, Kampo (Japanese medicine) and Egyptian medicine. It is a good herbal medicine for chronic anterior uveitis, small pox, chicken pox, skin cancer, conjunctivitis, rheumatoid arthritis, urinary tract infections, liver ailments, wound healing. Turmeric, also has the capability to treat digestive disorders, to reduce flatus, jaundice, menstrual difficulties, abdominal pain, loss of appetite, gallbladder and liver complaints, postprandial feelings of fullness, reported to show anti-inflammatory properties, anti-microbial and carminative actions. The main clinical targets of turmeric are mostly on digestive organs: in intestine for treatment of familial diseases such as adenomatous polyposis, for treatment of inflammatory bowel disease, and also for treatment of colon cancer. To treat arthritis, it is recommended to consume 8-60 g of fresh turmeric root three times daily. For dyspepsia, 1.3-3.0 g of turmeric is recommended[3].

9.0. Traditional Importance of Turmeric:

Turmeric has being used centuries ago all over the globe in therapeutic preparations. Turmeric is thought to have many medicinal properties and believed in Ayurvedic practices for strengthening the overall energy of body, reliving gas, improving digestion, dispelling worms, dissolving gallstones, regulating menstruation and reliving arthritis. It is being used as antiseptic for cuts, burns and bruises in most South Asian countries like India. In Pakistan, it is being used as anti-inflammatory agent and also can treat gastrointestinal discomfort especially with irritable bowel syndrome and other digestive disorders. In Asian countries, it is used to cleanse wounds and stimulate their recovery by applying it on burnt cloth and over the wound. Indians use turmeric, as a purifying blood agent and on remedy for skin conditions. Indian women's also use turmeric paste to remove superfluous hair.

In India, Bangladesh and Pakistan turmeric paste is applied to skin of bride and groom before marriage and is believed to make the skin glow and keep harmful bacteria away from skin[3]. Also, dried powder of turmeric is used as holy sign especially while during worship of Lord Satyanarayan in India. This dried powder is also used to worship Lord Malhar located in Jejuri village of Maharashtra and also Goddess Yellamma located in Solapur. India has a great traditional importance to turmeric and also is a worship sign for Goddess Tujlabhavani. In India, for any kind of disease turmeric milk is given to person suffering from any kind of disease and found to reduce the severity of disease.

Sunscreens nowadays contain several different formulations of turmeric. Turmeric is also being used in face creams and the formulations are currently being developed in several multinational companies. Turmeric is well-reported and found to treat various respiratory conditions such as asthma, bronchial hyperactivity and allergy and is being practioned in Ayurvedic medicine. It is a well-documented for treatment of liver disorders, anorexia, rheumatism, diabetic wounds, runny nose, cough and sinusitis. As per Ayurveda, turmeric is prescribed to use for conditions such as sprains and swellings from ancient times. Unani practitioners use turmeric as to expel out phlegm or kapha, and to improve blood circulation. Also is a main ingredient used in rice and bean dishes to improve digestion and reduce gas thereby, acting as cholagogue, stimulating bile production in liver and encouraging excretion of bile via gallbladder, which improves the body's ability to digest fats[3].

10.0. Medicinal Properties of Turmeric:

Turmeric is widely known for its medicinal properties, also in the form coloring agent, dye, in cuisines, and major used in Ayurvedic medicine in India. It has many useful components such as curcumin, its similar structure compounds such as bisdesmethoxycurcumin, desmethoxycurcumin etc[3]. Also, turmeric oil has many advantages and contain many volatile compounds. Despite of it has great traditional importance in India, as explained above. Still the research is going on turmeric, to cure life threatening diseases such as cancer, Alzehelmeir disease, also shows anti-inflammatory, anti-bacterial, anti-fungal, anti-oxidant, anti-carcinogenic and chemo-preventive properties[8]. Some are listed as follows:

10.1. Curcumin Induces Apoptosis:

Colorectal cancer is one of leading problem of death majorly in Western countries and is now increasing in Chinese population recently. For treatment of gastrointestinal cancer, chemotherapy is recommended as this is best and effective method to cure these types of cancers. Major active ingredient of turmeric, curcumin is reported to induce apoptosis in cell lines such as NIH 3T3, HL-60, K562, H520 and HeLa. Apoptosis is a very complex phenomenon and regulated process involving activation of certain molecules and initiation of cell death process. This procedure can be guided via the signaling pathway through the activation of caspases and recruitment of proteins in Bcl-2 family.

Some papers have reported that curcumin activates the molecules responsible for apoptosis pathway such as caspase-3, can cleave poly-ADP-ribose polymerase and up-regulate pro-apoptotic members such as Bax and Bad and this activity was found in cell-lung cancer. A similar case study was performed on HT-29 cells by using in-vitro techniques. Different concentrations of curcumin were applied on this cell lines ranging from 10-80 micromol/L and also at different time intervals of 8 and 24 hr.

It was determined that treatment with 40-80 micromol/L curcumin for 8 hr showed significant reduction in cell viability with 11.64% of cells died with a concentration of 80 micromol/L as compared to control. It also decreased cell proliferation after 24 hr of incubation and found to be a decrease by 89.13% at a concentration of 80 micromol/L as compared with control and had an inhibitory concentration (IC_{50}) at a concentration of 40.7 micromol/L. Also, after staining with Hoechst 33258 (stain used for nucleus) technique, it was reported that apoptotic cells significantly increased when exposed to curcumin after 16 hr incubation and found to undergo normal apoptotic pathway when stained by Hoechst stain[8].

10.2. Anti-Inflammatory Properties:

Turmeric has found most used in pharmacological activities, despite of being anti-microbial, anti-fungal, anti-oxidant it does show anti-inflammatory properties. Based on cell culture study and clinical trials and animal models it has been showed to be a therapeutic agent in conditions such as inflammatory bowel disease, pancreatitis, arthritis, chronic anterior uvetitis also there is ongoing research for the therapeutic use of curcumin and can be understood more deeply in future.

Research inidicates that curcumin is a highly pleiotropic molecule and has ability to interact with numerous molecular targets that are involved in inflammation. Basically, curcumin modifies the inflammatory response by regulating activity of cyclooxygenase-2 (COX-2), lipoxygenase, and inducible nitric oxide synthase (iNOS) enzymes. Also, inhibits the activity of production of inflammatory cytokines such as tumor necrosis factor-alpha, interleukin (IL) -1,-2,-6,-8 and -12, monocyte chemoattracant protein (MCP). The inhibition of COX-2 and iNOS is achieved by inhibiting nuclear factor kappa B which could be acquired with the use of curcumin. This factor is a ubiquitous eukaryotic transcription factor which is involved in inflammation, cellular proliferation, transformation and tumorigenesis. There was a study on animal models like mice on inflammation and edema and curcumin inhibited edema at doses between 50-200 mg/kg. A 50% reduction in edema was found at a dose with 48 mg/kg of body weight [9].

10.3. Anti-Bacterial Properties:

Commonly, humans suffer from bacteria's more than fungi, protozoans, parasites and other genetic diseases. As well as, simultaneously there has been extensive research over anti-microbial drugs from various sources from around 50 years. Despite of this success, there are still needs to find new anti-bacterial medicines due to evolution of multidrug resistant bacteria's. The anti-bacterial study on aqueous extract of turmeric rhizome demonstrated a minimum inhibitory concentration of 4-16 g/L and minimum bacterial concentration of value of 16-32 g/L against *S.epidermis* ATCC 12228, *Staphylococcus aureus* ATCC 25923, *Klebsiella pneumoniae* ATCC 10031 and *E.coli* ATCC 25922. Also the extracts of curcumin and curcuminoids using ethanol and hexane extract was carried out and test on 24 pathogenic bacteria with the help of animal models such as chicken and shrimps and showed the highest activity of anti-microbial activity with ethanol extract. Similarly hexane and methanol extracts were demonstrated and were found to be effectively against 13 bacteria namely, *Vibrio harveyi, V. alginolyticus, V. vulnificus, V. parahaemolyticus, V. cholerae, Bacillus subtilis, B. cereus, Aeromonas hydrophila, Streptococcus agalactiae, Staph. aureus, Staph. intermedius, Staph. epidermidis,* and *Edwardsiella tarda.* Even the turmeric oil, byproduct of curcumin manufacturer was reported to be effective against *B. subtilis, B. coagulans, B. cereus, Staph. aureus, E. coli,* and *P. aeruginosa.*

In-vitro studies were also held to find new drugs using curcumin extract and when investigated was found to be 3 new compounds namely, indium curcumin, indium diacetyl curcumin, and diacetyl curcumin which also possessed anti-bacterial properties [10].

10.4. Anti-Viral Properties:

Viruses, the acellular organisms are complex type of organism which evolve quickly in nature and cause infections. Hence forth, due to this reason there is a lack of effective medicines for most of viral diseases. The drugs which are effective on viruses are expensive and anti-viral

therapies are not well tolerated so there is a need for different substitutes for it. Turmeric contains various different phytochemicals which are useful in different biological activities such as anti-viral activity. Among the 15 different polyphenols, curcumin through inhibitory activity against inosine monophosphate dehydrogenase enzyme effect in either noncompetitive or competitive manner is suggested as a potent antiviral compound via this process. The study of different bioconjugates of curcumin, namely, di-*O*-tryptophanylphenylalanine curcumin, di-*O*-decanoyl curcumin, di-*O*-pamitoyl curcumin, di-*O*-bis-(*γ*,*γ*)folyl curcumin, C^4-ethyl-*O*-*γ*-folyl curcumin, and 4-*O*-ethyl-*O*-*γ*-folyl curcumin, against variety of viruses including parainfluenza virus type 3 (PIV-3), feline infectious peritonitis virus (FIPV), vesicular stomatitis virus (VSV), herpes simplex virus (HSV), flock house virus (FHV), and respiratory syncytial virus (RSV) assessed by MTT test showed the potent antiviral activity of curcumin and its bioconjugates against different viral pathogens for further studies. Phytochemicals of turmeric namely, curcumin and it's derivatives revealed inhibitory effect on HIV-1 provirus [10].

10.5. Anti-Fungal Properties:

After bacteria, fungi are second most to spread fungal infections and diseases among human beings. Due to use of turmeric in food as a cuisine, various researchers have studied the role of curcumin in controlling fungal related spoilage and fungal pathogens. In-vitro plant tissue culture techniques using effect of turmeric powder on fungal contamination was developed and found to be that as much as low 0.8 g/L turmeric powder is sufficient to inhibit fungal contamination. The methanol extract of turmeric demonstrated antifungal activity against *Cryptococcus neoformans* and *Candida albicans* with MIC values of 128 and 256 *μ*g/mL respectively. Similarly hexane extract of turmeric showed anti-fungal effect on Rhizoctonia solani, Phytophthora infestans, and Erysiphe graminis.

The strong antifungal activity of *C. longa* rhizome and its low side effect were the main reasons to investigate its probable synergistic effect with existing fungicides. The synergistic activity of curcumin with five azole and two polyene drugs including voriconazole, itraconazole, ketoconazole, miconazole, fluconazole, amphotericin B, and nystatin showed 10–35-fold reduction in the MIC values of the fungicides against 21 clinical isolates of *C. albicans*. Similarly, there were 200 clinical isolates of Candida species including *C. tropicalis, C. kefyr, C. krusei, C. guilliermondii, C. glabrata, C. parapsilosis,* and *C. albicans* indicated fungicidal activity for curcumin with MIC value of 32-128 microgram/mL. The mixture of curcumin and ascorbic acid against different strains of Candida also exhibited 5- to 10-fold reduction of MIC values compared to the time that curcumin was tested alone. These synergistic effects showed that curcumin in combination with different fungicide materials can significantly elicit synergistic activity to enhance the efficacy of existing antifungal strategies [10].

11.0. Nanotechnology Approaches for Curcumin:

Nanotechnology is emerging day by day and has lots of future applications. Among the all the applications of nanotechnology, use of nanoparticles has wide applications for enhancing the bioavailability and solubility of lipophilic compounds such as curcumin. Recently, nanoparticles have gained an immense popularity due to their therapeutic properties of protecting the drugs from enzymatic degradation by encapsulating it, providing controlled and prolonged release of drug, changing their pharmacokinetics, decreasing toxicity, and limiting non-specific uptake[11].

Absorption of curcumin in body is rapid procedure and is quite less. Animal models were studied for metabolism of curcumin when an oral dose of 500 mg/kg was fed to rat, it showed a peak plasma curcumin concentration of 1.8 ng/L[9]. Curcumin is metabolized quickly in body, conjugated in liver and excreted in form of feces. To compensate this problem nanoparticles such as liposomes, polymeric nanoparticles, micelles, nanogels, niosomes, cyclodextrins, dendrimers, silvers and solid lipids are emerging as one of useful alternatives that have been shown to deliver therapeutic concentrations of curcumin. Nanoparticles as mentioned above has improved main problems of curcumin such as low solubility, instability, poor bioavailability and metabolism, wound healing, Alzheimer's disease, inflammatory diseases and so on[11].

Fig.6. Mechanism of Liposome Targeting Curcumin inside Cell:

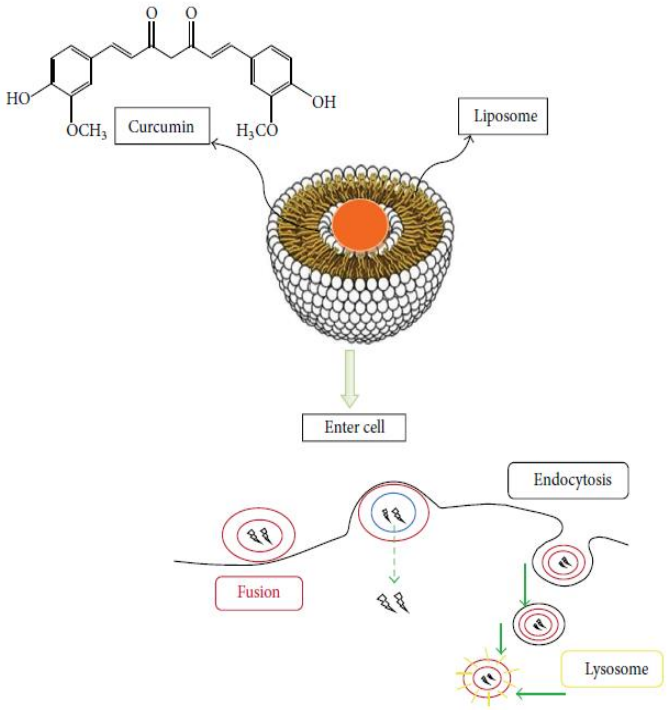

Image Source: (Julie S. Jurenka; Anti-Inflammatory Properties of Curcumin, A Major Constiuent of *Curcuma longa*: A Review of Preclinical and Clinical Research; Volume 14, Number 2; 2009)

12.0. Diseases of Turmeric Plant:

Curcuma longa used as condiment, dye, cosmetic, drug and in addition to that use in religious ceremonies especially in India. Turmeric itself contains many phytochemicals which has anti-bacterial, anti-fungal, anti-viral effects as mentioned above but still possess diseases [12].

12.1. Leaf Blotch:

Leaf blotch is a disease caused by *Taphrina maculans* and appears as small, oval, rectangular, or irregular brownish spots on abaxial and adaxial sides of leaves. This brown color, then turns into dirty yellow or dark brown. In severe cases plants represent scorched appearance and hence rhizome yield is greatly affected. This disease could be controlled by spraying turmeric plants with 0.2% mancozeb [12].

12.2. Leaf Spot:

This disease is caused by *Colletotrichum capsici* and appears to be brown spots of various sizes on upper surfaces of young leaves. The spots may be of irregular size, white or grey in color in centre. As the severity of disease prolonges, two or more irregular spots converge themselves and form an irregular patch almost covering entire leaf and leaves dry up. Due to this disease, rhizome growth and productivity is affected. But this diseases could be controlled by spraying carbendazim 0.5 kg/ha or 0.2% mancozeb solution or 0.2% copper oxychloride solution[12].

12.3. Leaf Blight:

It is caused by *Rhizoctonia solani* and spread of disease is characterized by appearance of necrotic patches with papery white centre of varying sizes on lamina which spread on whole surface leaving a blighted appearance. Mostly, the disease occurs in post monsoon season. The disease can be regulated with spraying 0.2% Bavistin or 1% Bordeaux mixture[12].

12.4. Rhizome Rot:

The disease is caused by *Pythium aphanidermatum*. It is characterized by the lower leaves of infected pseudostem show yellowing, collar region of psuedostem become soft and water soaked, resulting collapse of plant and inhibition of rhizomes. Treatment of this disease is usually spray of 0.2% mancozeb solsution for 30 minutes to seed rhizomes prior to storage and at the time of sowing prevents the disease. When the disease is detected, the beds should be drenched with 0.2% COC or 0.125% Metalaxyl-mancozeb[12].

12.5. Nematode Pests:

Majorly, root knot nematodes namely, *Meloidogyne spp*.and burrowing nematodes such as *Radopholus similis* are two main nematodes causing spoilage of turmeric. In Andhra Pradesh, root lesion nematodes such as *Pratylenchus spp.* is more common for spoiling turmeric plant. *Pochonia chlamydosporia* is applied to beds at the time of sowing seed rhizomes approximately 20 g/bed for management of nematode problems[12].

12.6. Insect Pests:

12.6.1. Shoot Borer:

Conogethes punctiferalis or shoot borer is the most common pest found in turmeric plant. The larvae of this insect bore into pseudo stem and feed on internal tissues. Appearance of bore hole on pseudo stem through which frass is extruded and the whithered central shoot is a typical symptom of plant being attacked by this pest. In adult form, it's a medium sized moth with a wingspan of about 20 mm; wings are orange-yellow with minute black spots. While fully grown larvae are light brown in color with presence of few hairs. This pest could be controlled with the spray of 0.1% malathion or 0.0125% lamda-cyhalothrin at 21 days of intervals during July to October. Eitherwise, initiate spraying when the first symptom of pest attack is seen on inner most leaf[12].

12.6.2. Rhizome Scale:

Rhizome scale is caused by *Aspidiella hartii* attack rhizomes in field especially at later stages of crop or during storage. Adult (female) scales are circular (about 1mm diameter) and light brown to grey and appear as encrustations
on the rhizomes. Especially feed on sap, and when rhizomes are severely attacked they become shriveled and get desiccated and inhibit its germination. For its pest management, timely harvest of rhizomes should be monitored. Treatment of seed material with quinalphos for 20-30 minutes before storage and before sowing. Eitherwise store rhizomes in sawdust along with dried leaves of *Strychnos nuxvomica*[12].

12.7. Other Pests:

Leaf feeding beetles such as *Lema* spp. feed on leaves especially during monsoon season and form elongated parallel feeding spots on them. It can be controlled through spraying of 0.1% malathion. Stephanitis typicus or lacewing bug attack the premature leaves causing them to turn pale and dry up. The pest infestation is more common during the post monsoon period especially in drier regions of country. Spraying with 0.05% dimethoate is effective in inhibiting this pest. *Panchaetothrips indicus* or turmeric thrips attacks mainly leaves causing them to roll, turn pale and dry up. Management of this pest could be obtained with spraying of 0.05% dimethoate[12].

13.0. Processing of Turmeric:

To enhance utility of farm products processing of these products must be carried out. Also, it does helps in marketing of farm products by making them more edible, palatable and attractive despite of it is convenience to use, storage and transport. Also, the government is funding by providing tax exemptions on processed products, subsidies and on packing costs. So, turmeric after being harvested undergoes following processing operations [13]:

13.1. Cleaning:

Processing is done usually of turmeric rhizomes and the first step after harvest is washing it with freshwater under pressure for removal of soil and other foreign matter [13].

13.2. Curing:

After cleaning procedure, cleaned rhizomes are submerged in hot water in tins and boiled. Cured rhizomes are then let to drain water and dried in a bamboo basket. This process is essential to give attractive color, kill the growth of fresh turmeric, eliminating odor, reduces time of drying and also ensures even distribution of color and gives better quality product by gelatinization of starch in rhizomes [13].

13.3. Drying:

It requires 12-15 days of sun exposure for drying process, till it becomes thoroughly brittle and can be broken by finger pressure. Drying results in reduction of moisture content in rhizome by 8-10%. Artificial dryers or mechanical dryers are also used using cross flow heated air dryers at 65^0C and found to provide best products, especially for brighter colored product from turmeric than sun drying [13].

13.4. Polishing:

Polishing of rhizomes is done by rubbing hands under several folds of gunny cloth or using polishing drum water [13].

13.5. Coloring:

After polishing, rhizomes are treated with emulsion or mixture of turmeric powder and alum under continuous shaking in basket to obtain brighter and uniform yellow color to turmeric rhizome [13].

13.6. Grading:

Grading is a process to sort or to differentiate product on the basis of their different qualities of turmeric rhizomes. Mostly, it is done manually which is time consuming either wise by mechanical reciprocating type grader. Grading for both turmeric as well as its powder is performed as per Indian Agmark Standards [13].

13.7. Milling:

Generally, turmeric is milled on home scale in flour mills to obtain turmeric powder. It is usually carried out in two phases first breaking rhizomes into smaller pieces and then powdering them to desired fineness [13].

13.8. Packaging:

Packaging is act of ‘putting of content in the market in a size pack which are convenient for buyers’ as defined by Archarya and Agarwal. Well processed turmeric is kept in double burlap new gunny bags which are properly fumigated prior to packaging. While turmeric powder is packed into fiber board drums, multi wall bags and tin containers [13].

13.9. Storage:

Processed turmeric bags are stored in pit made on raised ground with sides and bottom padded with a thick layer of paddy straw [13].

13.10. Marketing:

Turmeric is marketed through terminal markets located in producing states and other major markets [13].

14.0 Economical Status:

14.1. Indian Scenario:

India is the largest consumer, producer and exporter of turmeric in world. The country consumes 80 percent of it's turmeric production and also exports it. It is grown in 25 states of India of which Andhra Pradesh, Tamil Nadu, Karnataka and Odisha being the leading poducers. Other states like such as Gujarat, West Bengal, Assam, Meghalaya and Maharashtra also are the main producers of turmeric. The area under cultivation of turmeric in India is 1.73 lakh hectares with a total production of 8.55 lakh tone per year. Andhra Pradesh, banged first in area as well as production of turmeric during the year 2005-06 with an area of 69990 hectare (40.46 %) and production of 518550 tonnes (60.60 %) followed by Tamil Nadu with acreage of 25970 hectare (15.01 %) and production of 143358 tonnes (16.75 %)[2].

Turmeric is now regarded as cash crop due to its increasing demand and hence it is now a good income source in India. When comparison with rice and wheat it is more expensive than both in procedures from land preparation to harvesting but the return is doubled then the combined return of rice and wheat [14].

Table No.5. Comparison of rates of Turmeric, Wheat and Rice:

(Rs/acre)

Costs structure	Turmeric	Wheat	Rice
Land preparation	184	1375	1155
Sowing	20000	478	278
Fertilizer and weed control	2050	1965	2186
Irrigation	428	300	300
Harvesting and threshing	-	1000	-
Human labour			
Land preparation	463	400	355
Sowing	400	372	300
Fertilizer application and weed control	736	400	450
Irrigation	400	1000	2000
Harvesting and threshing	2987	100	1911
Transportation	400	50	350
Interest on variable costs @9 % for half crop period	1253	335	418
Total variable costs	29117	7775	9703
Gross Returns	119000	35100	25500
Returns over variable costs	89883	27325	15797
Variable cost return ratio	4.09	4.51	2.63

Image Courtesy: (Udeshnatalukdar And Kamal Vatta; Relative Profitability Of Turmeric Cultivation in the Green Revolution Belt: A Case Study in Hoshiarpur District of Punjab; 2015.

As from the table one can conclude that seed of turmeric is more expensive than that of wheat and rice, also the expenses for labour power are high for turmeric. After all, variable costs for turmeric is Rs. 29117 per acre; for wheat it is Rs. 7775; for rice it's Rs. 9703 which then results that costs for turmeric is 67 percent higher than that of rice and wheat. But the gross returns from turmeric was found to be Rs. 119000 per acre and to that of combined return of rice and wheat was found to be Rs. 60600 per acre which implies that gross return from turmeric was approximately doubled then that of gross return from combined rice and wheat cultivation. Hence, it clearly depicts that turmeric cultivation was more remunerative then to rice and wheat cultivation. Also, it not only helped farmers in raising their income but also gave opportunity for labour employment as it is more labour intensive.

14.1.1. Employment through Turmeric:

Cultivation of turmeric resulted in gross significant amount of employment generation which occurred at farm level due to its laborious cultivation. Turmeric cultivation per acre would require 33 man for doing processes from land preparation to transportation. The harvesting process of turmeric plant was a very labour intensive process and would require 54.4 percent labour use. This was followed up by land preparation and weed control accounting of 9.1 percentile labour use. It is a good way for employment generation at farm level. Following chart shows different processes and their labour use[14]:

Table No.6. Labour Use per Process:

Particulars	Labour use (Man days/ acre)
Land preparation	3(9.1)
Sowing/planting	2(6.1)
Fertilizer application	2(6.1)
Irrigation	2(6.1)
Weed control	3(9.1)
Harvesting	18(54.4)
Storage	1(3.0)
Transportation on farm and to factory	2(6.1)
Total employment generation	33(100.0)

Image Courtesy: (Udeshnatalukdar And Kamal Vatta; Relative Profitability Of Turmeric Cultivation in the Green Revolution Belt: A Case Study in Hoshiarpur District of Punjab; 2015.)

14.2. International Scenario:

Nowadays, India has topped in production, consumption and exportation of turmeric in the world. Following it by China which is second largest supplier of turmeric in world scenario and is followed by countries in Southeast Asia, Carribean and Latin America. Other producers in Asia include Bangladesh, Pakistan, Sri Lanka, Taiwan, Burma and Indonesia. Carribean and Latin American countries such as Haiti, Jamaica, Costa Rica, Peru and Brazil also cultivate turmeric. Basically, there are two main dominant types of turmeric in world market: 'Madras' and 'Allepy' which are named after the regions of production in India

.

Allepy species, the orange-yellow flesh turmeric is dominant in U.S. and are preferable as a spice and food colorant. This species contains about 3-5.5% volatile oils, 4-7% curcumin. In comparison to Madras only contains 2% of volatile oils and curcumin. Despite of it Madras type is preferred in British and Middle Eastern markets, due to its brighter, intense and lighter yellow color which is better suited for mustard paste, curry powder in cuisines. Surprisingly, US turmeric is considered as spice by food industry but FDA classified it as food colorant. Majorly, India exports turmeric and UAE, Japan, US, Sri Lanka, Malaysia, UK all-together accounts for 65% of Indian turmeric products[2].

14.3 Exports about Turmeric:

India produces 80% of total world turmeric production and exports 60% of it. Major export varieties of turmeric include: Allepy finger turmeric, Rajapuri, Madras and Erode varieties. The processed forms of turmeric exported are dry turmeric, fresh turmeric, turmeric powder, and oleoresin. The major importer of turmeric is United Arab Emirates accounting of 18.35% followed up by U.S. of 11.44 %. Asian countries consume turmeric more than American and Europe countries. About 97% of U.S. imports turmeric from India and Japan largely imports from Taiwan. Nowadays, turmeric d/demand is being increasing day-by-day due to natural product as food additives or as natural food colorant. Besides it, has got additional medicinal features such as medicinal research demonstrating anti-cancer, anti-viral activities[2].

15.0. Product Development from Turmeric:

Turmeric is widely used in India and has got all aspects as being economical, traditionally important, being a cash crop and having many medicinal properties. Almost used in all Indian cuisines and this spice has almost no calories (1 tablespoon = 24 calories) and zero cholesterol. Also rich in dietary fiber, iron, potassium, magnesium and vitamin B6[17].

Turmeric is often regarded as "Queen of Spices" and Ayurvedic and Chinese medication uses and utilizes turmeric excessively to cure various health issues[18].
Turmeric is being used widely in use for various purposes:

15.1. Brighten Your Pearly White:

Turmeric is known for its staining prowess and is commonly used to whiten the teeth. Just take a pinch of turmeric powder mix it with water and form slurry then apply it to teeth once using toothbrush per day. In four days, one could see the change in result and 80% of yellow teeth turns white[19].

15.2. Customize Foundation:

Different cosmetics, contains bad chemicals which on prolonged exposure shows many side effects like pimple formation, skin rashes and so on. Turmeric is believed to brighten the skin and prevent the skin from bacterial and fungal diseases[19]. To apply turmeric on face, take a pinch of turmeric powder, add few drops of lemon juice and finally mix it with honey, apply on face and leave it for 10 minutes. Apply in a week for twice. It helps in reduction of dark circles, pimple formation, dark heads and pimple prevention.

15.3. Spice Up Your Soap:

If one makes homemade soaps adding several teaspoons of turmeric to it will not dial up its odor, but will boost its skin friendly benefits as well[19].

15.4. Save Your Scalp:

Many swear by combination of olive oil and turmeric to deter dandruff and to improve overall condition of scalp. Make a mixture of turmeric powder and oil either coconut or olive oil, massage into your scalp and leave it for 15 minutes, then shampoo and style as usual[19].

15.5. Embellish Temporary Tattoos:

Turmeric is used to create golden mehndi, or to improve and add a pretty secondary color to an extant henna tattoo[19].

15.6. Diminish Sprain Strain:

Homeopathic sprain treatment involves making a paste using one part salt and two parts turmeric and enough of water to make it spreadable. Apply to affected joint and wrap it in old cloth so as the stain could come on cloth. Leave it for 20-60 minutes, once a day. Also studies have shown that turmeric reduces sprain swelling and makes the effects of an proteolytic enzyme called bromelain (derived from pineapple, has anti-inflammatory effect) stronger[19].

15.7. Help Tame Swimmer's Ear:

Natural remedy , the aficinados recommend using warmed garlic oil to push water from ears affected by swimming. This could be acquired if turmeric is added to garlic oil and shows a better result than oil alone[19].

15.8. Soothe A Sick Stomach:

Since centuries turmeric is used to quell bellies that aren't behaving properly. The National Institutes of Health (NIH) recommends 500 mg of turmeric four times daily to treat an upset stomach[19].

15.9. Love Your Liver:

As regarding to Medical University Graz in Austria it showed that curcumin delayed liver damaged that could eventually lead to cirrhosis and hence must be a part of our diet in form of spice daily.

15.10. Make Longevity Tea:

Dr. Andrew Well reported that people in Okinawa, a Japanese nation with world's longest average life span said to drink turmeric tea everyday. To make this tea, boil four cups of water, add one teaspoon of ground turmeric allow it to simmer for 10 minutes, strain and add ginger or honey as per taste[19].

15.11. Use As Dye For Spicy Tie-Dyed Tees:

Turmeric is an excellent dye which stains fabrics easily. Add three tablespoons of turmeric to a pot of boiling water, let it to simmer for a while and dye bath is ready[19].

15.12. Blend Your Own Curry Powder:

There's one thing turmeric famous for, it's starring role in curry powder. Making your own curry blend is simple and tastes remarkably bright and fresh and you can customize it to reflect a your personal taste. It is also an main ingredient spice in cooking[19].

15.13. Make Dishes Delicious:

No uses of turmeric would be completed without reminding the wonderful food that can be made with turmeric even if it may not be the most surprising use on list[19].

15.14. Make Meat Safer:

Kansas State University Researchers discovered that adding turmeric to meat can reduce levels of heterocyclic amines (HCA's) upto 40% thereby reducing risks of cancer[19].

15.15. Bake A Cake:

These types of cakes are Lebanese dessert which is not too sweet and has odd little earthy kick to it compliments of turmeric[19].

16.0. Conclusion:

Turmeric also known as “Indian Saffron”, “Golden Saffron”, “Golden Spice” and “Queen of Spice” is believed to be Indian origin monocot plant. This plant has got many medicinal properties such as anti-oxidant, anti-bacterial, anti-fungal, anti-viral, anti-inflammatory, anti-carcinogenic and anti-mutagenic. Despite of this, it also has got a great social and traditional importance as it is used as a sign to Worship Lord Malhar and Lord Satyanarayan and is also applied to grooms and brides before marriage in India. It is also used as a dye for fabrics, coloring agent, and main ingredient in every Indian dishes in form of curry. India is the largest producer and consumer of turmeric and its product and exports 80% of total world population. It also has shown a good employment generating sector and hence is a cash crop. Turmeric could be grown easily in both *in-vitro* and in-vivo. Also it requires proper loamy soil and moderate amount of water and is a perennial plant which completes its life cycle in 9 months.

Turmeric plays a direct or indirect role in each and every kind of disease whether it would be bacterial, fungal or viral origin starting from a simple fever to life threatening disease such as cancer. It must be consumed daily and studies have shown that higher doses of turmeric wouldn’t harm or give any side effects to human body. Turmeric contains many phytochemicals and volatile oils such as curcuminoids and its derivative and *in-vitro* studies have shown that these phytochemicals has anti-microbial, anti-viral and anti-carcinogenic properties even at low concentrations.

Studies have shown that curcumin, a major ingredient of turmeric plant is absorbed poorly in human body and gets excreted in form of feces. So as to overcome this condition a recent emerging field called nanotechnology has found useful to target curcumin in cells with the help of nanoparticles. Despite of it, turmeric faces a problem of having diseases due to bacteria, fungi and insect pests. But can be controlled with the help of certain spray solutions such as mancozeb.

Despite of it, there are various home remedies or uses of turmeric in home scale which one could use in home easily. Also, it has got some advantages such as used as a teeth whitener, as pimple prevention on face, as a spice in Indian dishes, as to decorate your clothes in form of dye and so on.

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