CHAPTER III

RESULTS AND DISCUSSIONS

(A) PHYSICAL PARAMETERS

Sharma *et al.*,(1990) in peach leaves affected by *Taphrina deformans*, reported increase in Average leaf weight and Average leaf thickness of infected leaves than healthy leaves. Bole and Bharucha (1954) reported data on osmotic relationship in leaves of *A. alba* and concluded that older leaves always has greater water content and higher osmotic pressure than young or healthy leaves. Jamale (1975) reported increase in leaf thickness, average leaf weight and moisture content in senescent leaves of mangroves.

Our results of the present investigation are depicted in Table No.(1). It is clear that increase in Average leaf weight and Average leaf thickness in infected leaves of all the varieties of turmeric viz. Salem, Rajapuri and Krishna. The infected leaves of Salem are highly thickened as compared to Rajapuri and Krishna varieties. Diseased plant leaves shows chlorosis due to pathogenic infection and show senescent appearance. Our observations also show more considerable reduction in leaf area of infected leaves than the healthy ones. Meiri and Poljakoff-Mayber (1967) reported the reduction in leaf area, due to reduction in cell size. The density of the healthy and infected leaves were calculated and it was found that the density is higher in healthy leaves than that of infected ones. The low density in infected leaves is due to the increased cellular volume and cellular water content.

Table No. 1 : Physical parameters of healthy and diseased leaves of turmeric varieties Salem, Rajapuri and Krishna.

Sr. No.	Parameters	Salem			Rajapuri		Krishna	
		Healthy	Infected by blotch	Infected by spot	Healthy	Infected by blotch	Healthy	Infected by blotch
1.	Average leaf-weight in g (A)	12.90	13.00	14.00	15.00	16.00	18.00	18.50
2.	Average leaf-area in cm^2 (B)*	707.82	625.00	637.00	816.00	714.00	890.63	729.35
3.	Average leaf-thickness in 1 cm (C)	0.013	0.015	0.017	0.010	0.012	0.012	0.016
4.	Average leaf-volume (B X C) cm^3	9.20	9.37	10.82	6.65	8.56	10.68	11.66
5.	Leaf-density A/BXC g/Cm^3	1.40	1.38	1.29	2.25	1.86	1.68	1.58

* factor suggested by Rao and Swamy (1984) for leaf-area = 0.72.

(B & C) MOISTURE, DRY MATTER PERCENTAGE AND RELATIVE WATER CONTENT

Our results (Table No.2) show the effect of infection on the moisture percentage of turmeric. The data show that due to infection the moisture percentage increases in all the varieties of turmeric viz. Salem, Rajapuri and Krishna. Sharma et al., (1990) reported higher moisture content of diseased leaves than the healthy leaves of peach leaves attacked by leaf-curl disease. These changes are due to excessive hypertrophied and enlargement of leaves. Llive (1976) reported that Taphrina deformance infected peach leaves were 7 times heavier than healthy leaves and contain 2 to 3 times more water.

The diseased plant leaves show disapperance of chlorophylls due to cause of pathogen and show senescent appearance. Joshi and Mishra (1970) have reported more moisture content in senescent leaves of Clerodendron inerme. Similar results were found by Jamale (1975), Deshpande (1981) and Bhivare (1984) in mangrooves, sugarcane and Alternanthera respectively. Rane (1989) reported similar results in groundnut. It may be stated that infected leaves show increased water content. This increase in moisture percentage may be due to more accumulation of ions in the infected leaves of all turmeric varieties viz. Salem, Rajapuri and Krishna. So as to reduce the toxicity of ions by dilution as indicated by Jennings (1968).

The dry matter percentage decreases in infected leaves of all turmeric varieties. Johari (1975) reported decrease in the dry matter percentage of mosaic virus infected Carica papaya L. The result represented lower cry matter content in the infected leaves than the healthy leaves. It might be due to lower amount of chlorophyll alongwith an enhanced activity of enzymes.

(D) ORGANIC - CONSTITUENTS

(a) Chlorophylls

The chlorophylls are the integral part of energy trapping pigments in the process of photosynthesis. They dependent on reserve food material and dark respiration for energy and reducing power, many workers have reported reduction in chlorophyll content due to infection (Magyarosy and Malkin, 1978, Waseem et al.,1979, Johari and Padhi 1981).

Several workers have shown decrease in chlorophyll content due to infection. Sankpal and Nimbalkar, (1980), Thite et al.,(1980), Balasubramanian (1981), Singh et al., (1980) Dhumal et al., (1982) have shown reduction in chlorophyll content in diseased plants.

Many reports on fungal infection have noted similar trends Allen (1942) & Scot and Simillie (1963) suggested the decrease in chlorophyll content in wheat and Barley leaves infected by powdery mildew respectively. Krishnamani and Laxshaman (1976), reported that there was reduction in total

Table No. 2 : Moisture %, Dry matter %, Relative water content and chlorophylls in healthy and infected leaves of turmeric varieties viz. Salem, Rajapuri and Krishna

Sr. No.	Parameters	Salem			Rajapuri		Krishna	
		Healthy	Infected by blotch	Infected by spot	Healthy	Infected by blotch	Healthy	Infected by blotch
1.	Moisture percentage	80.74	83.20	83.57	79.41	80.66	82.00	85.00
2.	Dry matter %	19.20	16.80	16.43	20.59	19.34	18.00	15.00
3.	Relative Water Content in %	78.68	79.84	80.52	76.31	78.68	77.82	81.57
4.	Chlorophyll - a	38.53	37.53	30.71	60.70	30.71	55.16	45.80
5.	Chlorophyll - b	34.00	32.18	28.11	52.12	28.11	47.59	44.46
6.	Total chlorophylls (a+b)	72.53	69.71	58.82	112.82	58.82	102.75	90.26
7.	Ratio a/b	1.33	1.16	1.09	1.16	1.09	1.16	1.03

Chlorophylls values are expressed in mg 100^{-1} g fresh leaves.

chlorophylls, due to the infection of fusarium in cotton. Kaur and Deshpande (1980) also reported the same observation in cowpea infected by Erysiphae. Similarly Upadhyay and Duivedi (1979) same trends in eucalyptus.

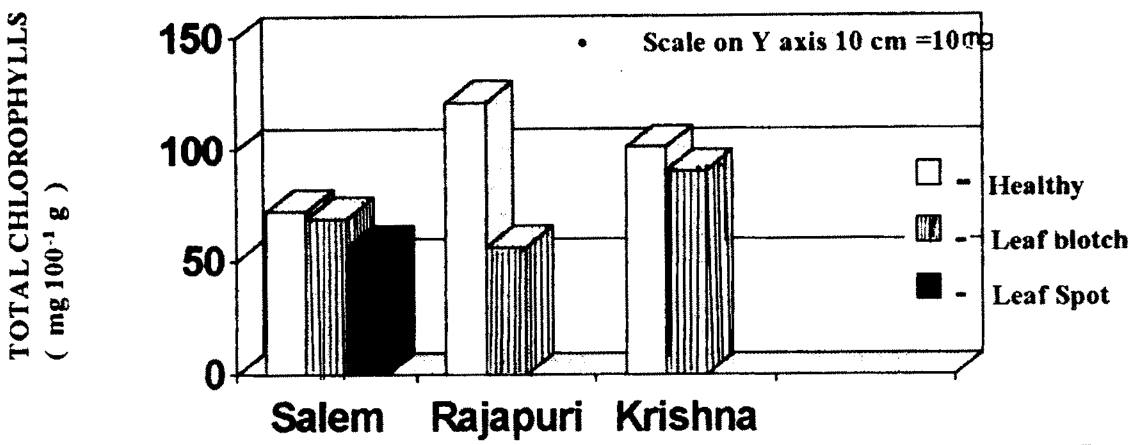
In the present investigation we analysed the healthy and infected leaves of turmeric varieties Salem, Rajapuri and Krishna and the values are depicted in the Table No.(2) and Fig. No. (1). It is clear from the table that the values show reduction in chlorophyll content in the diseased leaves of all the three varieties. It was also found that there is greater reduction of chlorophyll content in infected leaves of Turmeric caused by Taphrina than infection caused by colletotrichum. The ratio of chlorophylls also decreased in all varieties of Turmeric infected by both Taphrina and colletotrichum.

This decrease in chlorophyll content may be due to metabolic distrubances as reported by Upadhyaya and Duivedi (1979) or loss of structural integrity of chloroplast by Chen and Chen (1974), Mitra and Sengupta (1980) or lower rate of synthesis and accelerated berak down as reported by Mayer *et al*., (1960), Tugnawet (1977), Duggal *et al*.,(1981).

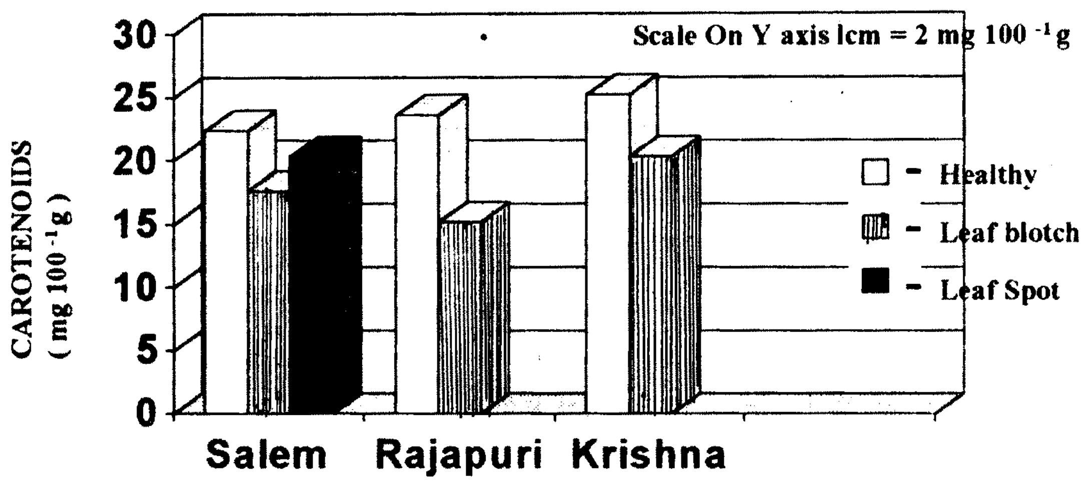
The decrease in ratio of chlorophyll a/b due to infection is also reported by Tugnawet (1977). According to Balliss (1970) Chinnadurai and Nair (1971), Parthasarthi *et al*., (1976), Kaur and Deshpande (1980) Srinivasan (1982) the decrease in Chlorophyll may be due to utilization or increased activity

Total Chlorophylls, Carotenoids & total Carbohydrates content in Healthy & Infected leaves of Turmeric varieties, Salem, Rajapuri & Krishna.

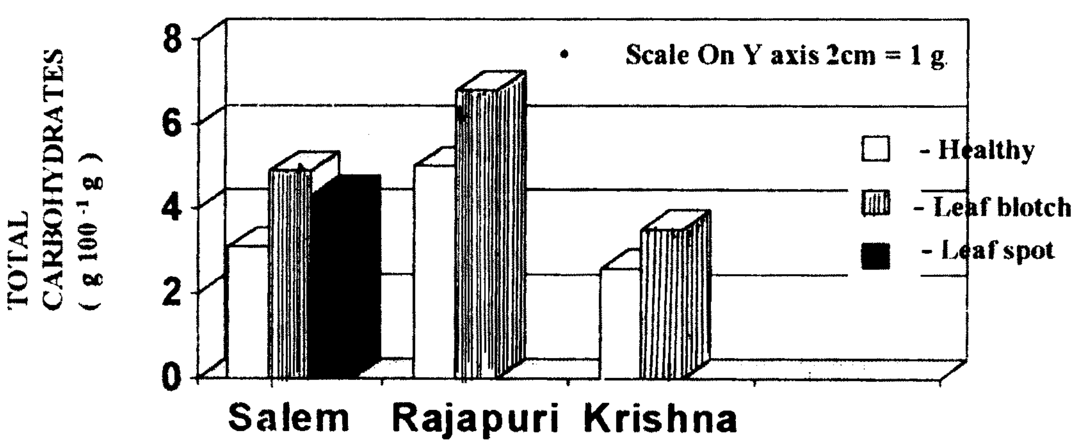
TOTAL CHLOROPHYLLS



CAROTENOIDS



TOTAL CARBOHYDRATES



of chlorophyllase. Patel and Vaishnav (1986), Naik et al.,(1988), Nagaraja and Thite (1988), Nagaraja (1990), Chou et al., (1995) reported decrease in chlorophyll content in infected leaves.

(b) **Carotenoids**

Carotenoids are the aecessary photosynthetic pigments. Singh et al., (1986) reported reduction in carotenoids of downy mildew infected leaves of opium. Naik et al.,(1988) also observed greatly reduction in carotenoids due to infection in betel vine leaves.

Our Results of the present investigation are depicted in Table No.(3) and Fig. No. (1). It was clear that there is decrease in carotenoids in the all turmeric varieties after infection. The maximum reduction in carotenoid content was observed in Rajapuri variety. In Salem variety higher reduction in carotenoid content in colletotrichum infected leaves than in Taphrina infection.

This decrease in carotenoid content may be due to the entry of pathogen in host tissue and metabolic disturbances leading to the decrease of synthetic activity of carotenoids.

(c) **Polyphenols**

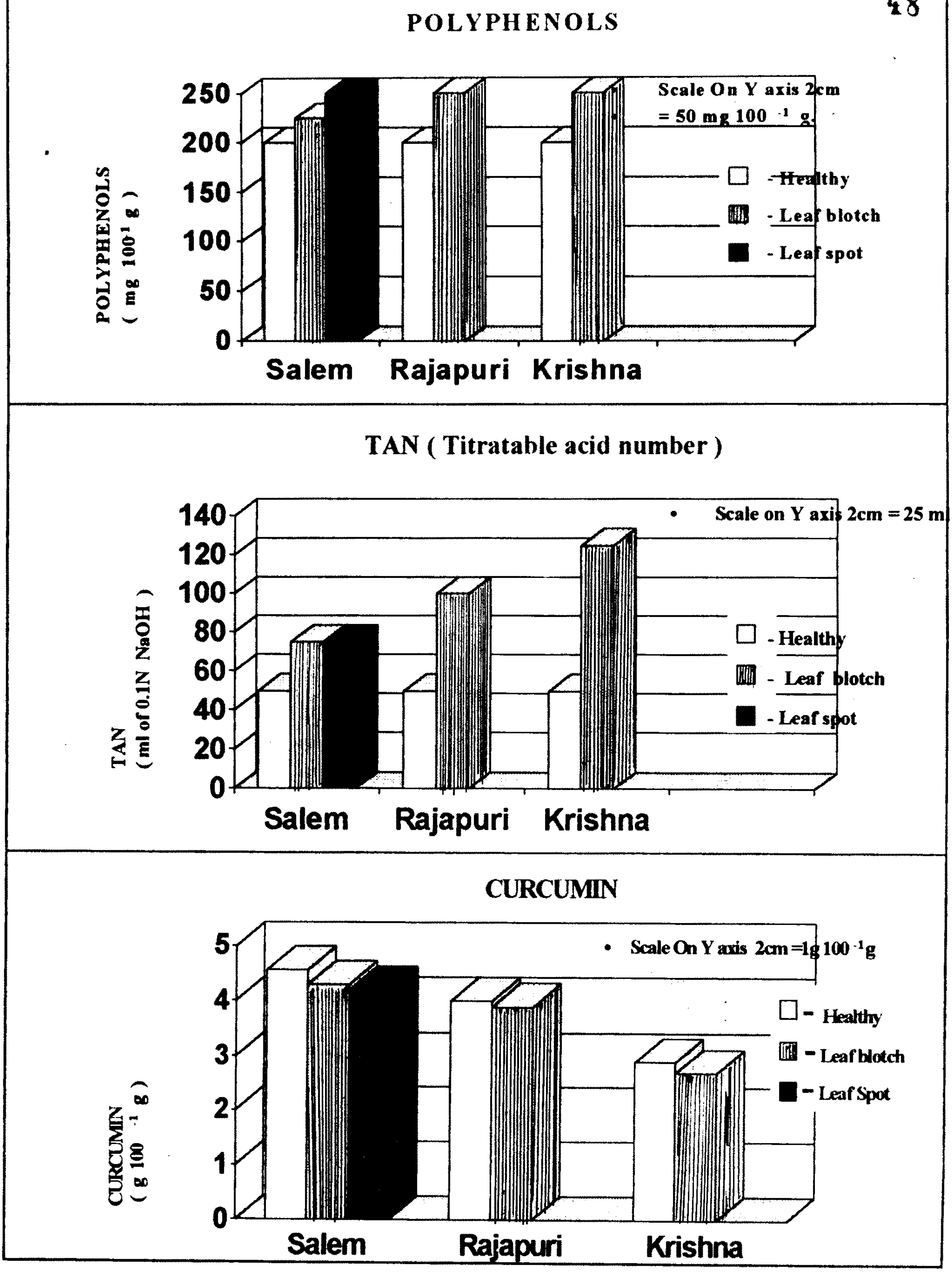
The compounds having one or more aromatic rings with hydroxyl group are commonly called "phenols". The compounds with more than one hydroxyl groups are called polyphenols.

Phenolic compounds play a very important role of decrease resistance as reported by several workers (Pridhan 1960, Wood 1967, Kosuge 1969, Farkas and Kiraly 1962, Cruickshank et al., 1964, Tomiyani 1963, Rohringar and Samborki 1967). Again it was reported that oxidation products of phenol also help in disease resistance.

The values of polyphenols in the present investigation depicted in Table No.(3) and Fig. No.(2). It is clear that the infected leaves of turmeric show increased polyphenols than the healthy leaves. Several workers have reported either increased or decreased content of polyphenol in healthy and infected plants e.g. Parthsarthi et al., (1970) in sandal spike disease, Prasad and Sahambi (1980) in Sisamum affected by sessamum phyllody. Mitra and Majumdar (1977) and Srinivasan (1983) reported in MLO infected leaves of Brinjal and areca palm respectively, meanwhile Arya et al., (1981) observed in pearl millet infected with Sclerospora. Jindal et al.,(1979) in muskeion affected by powdary mildew. Kumar and Rao (1980), Sankpal and Nimbalkar (1980), in wheat and sugarcane affected by Alternaria and smutted sugarcane respectively. Reddy et al., (1981) in Areca palm caused by canoderma. Agarwal et al.,(1982), Singh and Singh (1983) in Turmeric and Guava affected by Taphrina and Aspergillus respectively have reported increase in polyphenols.

Our present investigation showed that there is increase

Polyphenols, T. A. N. & Curcumin content in Healthy & Infected leaves of Turmeric varieties, Salem, Rajapuri & Krishna.



in polyphenol content in infected leaves of all the three varieties of turmeric viz. Salem, Rajapuri and Krishna caused by Taphrina maculans and collectotrichum capsaci. Thus increased polyphenol content in infected leaves showed the greater resistance to disease.

(d) **Titratable Acid Number (TAN)**

During the metabolic processes various acids were synthesised. Acidity status of the leaves can be determined by titrating the plant extract against standard alkali, TAN can also be defined as number of ml of decinormal NaOH required to neutralise the acid content from 100g of fresh plant material.

The increase in TAN value due to infection was reported by Kulkarni and Kulkarni (1976) in mango leaves infected by capnodium ramosum cooks. Thite et al., (1980), also suggested high TAN values in teak leaves affected by powdery midlew. Similarly other workers Jagtap et al.,(1981), Hardikar (1978), Sasikumaran et al., (1979), Tutenor (1981), Nagaraja and Thite(1988) have recorded increased TAN values in infected plants.

The increased rate of respiration may be responsible for the increased level of TCA cycle intermediates which in their turn, increase TAN values. Increase in TAN values due to the stimulation of respiration there by reducing organic acids of the TCA cycle in the free pod.

In our present investigation the TAN values are increased in infected leaves of all the three varieties of Curcuma longa L. viz. Salem, Rajapuri and Krishna. TAN values are recorded in Table No. (3) and Fig. No.(2). Enhanced chlorosis and breakdown of many metabolities leading to increased TAN in Taphrina and Colletotichum infected leaves of turmeric varieties.

(e) Curcumin

Curcumin is an orange yellow coloured pigment present in the plant turmeric. Curcumin has an empirical formula $C_{22}H_{20}0_6$ and molecular weight 368.39. Its nomenclature is bis (4 - hydroxy, 3 - methoxy (innamoyl) - methane. It is soluble in methanol, ethanol,acetone, dichloro ethylene, alcohol and glacial acetic acid.

Reddy and Rao (1978) recorded variation in curcumin content in different cultivars and at different fertilizer dosages Kostee (1994) observed that the curcumin was accumulated more in salt stressed plant.

Our results depicted in Table No. (3) and Fig. No.(2) show slight decrease in curcumin content in infected plant of turmeric. The more decrease in curcumin was observed in Salem variety infected by Taphrina and Colletotrichum. However curcumin content is higher in Salem variety than Rajapuri and Krishna variety. Curcumin content is the least in Krishna variety. This decrease in curcumin content may be due to entry of

Tabel No. 3 : Carotenoids, Polyphenols, TAN and Curcumin contents in Healthy and Infected leaves of turmeric varieties, Salem, Rajapuri and Krishna

Sr. No.	Parameters	Salem			Rajapuri		Krishna	
		Healthy	Infected by blotch	Infected by spot	Healthy	Infected by blotch	Healthy	Infected by blotch
1.	Carotenoids	22.4	17.6	20.4	23.6	15.2	25.2	20.4
2.	Polyphenols	200.0	225.0	250.0	200.0	250.0	200.0	250.0
3.	TAN	50.0	75.0	75.0	50.0	100.0	50.0	125.0
4.	Curcumin	4.57	4.37	4.20	4.00	3.92	2.91	2.70

* Values are expressed in mg 100^{-1}g fresh weight for carotenoids and polyphenols.

* Values are expressed in ml of 0.1 N NaOH for TAN

* Values are expressed in g 100^{-1} g for Curcumin.

pathogen and change in metabolic activities in host tissue.

(f) **Carbohydrates**

The pathogenic fungi generally utilise ready carbohydrates of host plants for their life activities. Carbohydrates are usually available in the complex forms. The fungi have the ability to convert them into simple water soluble sugars and utilize. The fungi utilize monosaccharides directly while oligo, poly saccharides are firstly converted into simple compound and then utilized.

Many workers have reported increase in reducing sugar content while few have reportted decrease in it. Kaley and Nagaich (1975), Kaley et al., (1977), Nagaich (1978) have reported considerable increase in reducing sugar content in different infections of potato leaves. Hegde and Munjal (1971) reported greater quantities of reducing sugar in bean infected with colletotrichum. Similarly increase in sugars have been reported by Sankpal and Nimbalkar (1980) in Smut affected sugarcane. Dhumal and Nimbalkar (1989) in GSD affected sugarcane; Mohaptra (1982) in maize infected with sclerospora, Goel et al., (1983) in coriander infected by protomyces, Karande and Hegde (1984) in Bajra affected by Downy Mildew fungus. Patel and Vaishnav (1987) reported by increase in soluble sugars. Nagaraja (1990) reported increase in sugars while Achar (1994) reported reduction in reducing sugar and starch in redish infected by perinospora. Chou et al., (1995) reported accumulation of soluble carbohydrates in Arabidopsis infected by <u>Albugo</u>.

Our results of present investigation are depicted in Table No. (4) and Fig. No. (1). In turmeric leaves infected by <u>colletotrichum</u> shows increase in reducing sugars. The highest reducing sugars were observed in Rajapuri variety. In Salem variety reducing sugars increased higher due to infection by <u>colletotrichum</u> than the <u>Taphrina</u> infection.

The different opinions have been attributed to greater reducing sugar content in diseased plants. Okasha <u>et</u> <u>al</u>., (1968) marked the accumulation of reducing sugar due to the distruction of normal phloem transport or due to the release of Amylase in the host cell. While Parthsarthi (1977) suggested increase in reducing sugar due to phloem necrosis. On the other hand Joshi (1976) Billet <u>et</u> <u>al</u>., (1977) Ghorpade and Joshi (1980), Chen and Hou (1981) and Mitchelli (1982) attributed that due to manifloid increased activity of invertase and synthetase might increase the reducing sugar in diseased plants.

Thus increase in content of reducing sugars in turmeric infected by <u>colletotrichum</u> and <u>Taphrina</u> may be due to enhanced activity of enzyme invertase and amylase also.

Different conflicting reports are available regarding total sugars. Kaley <u>et</u> <u>al</u>., (1977) Nagaich (1978), Srinivas and

Chelliah (1979) reported accumulation of total sugar in MLO infected sandal, potato and Brinjal. Similarly report was done by many workers like Vidhyasekaran et al., (1974) in Setaria affected by rust Sivaprakasam et al., (1974) in brinjal affected by Verticillum. Suzuki (1975) reported in potato infected with melampsora. Hwang et.al., (1983) in Barley infected Erisiphae.

On the contrary lower content of total sugars are reported by Nagvi (1977) Kapur et al., (1978). Sankpal and Nimbalkar (1980), Agarwal et al., (1982) Mahaptra (1982) Goel et al., (1983) Singh and Singh (1983) reported lowered total sugar content in groundnut affected Cercospora, datepalm, sugarcane infected by Smut, turmeric infected by Taphrina coriander infected by protomyces.

Our investigation also shows decrease in total sugar content in all varieties of turmeric infected by colletotrichum. The highest reduction was observed in salem variety affected by Taphrina.

Change in starch content following infection have been observed in many foliage diseases. The general pattern is an initial decrease followed by a marked increase with heavy accumulation around the margins of lesion.

The facultative parasites such as cercospora also causes a depletion of starch. Kolandaisamy (1964) reported the reduction in starch in Banana leaves and initial major content of groundnut leaves infected by _Cercospora_ _personeta_. On the contrary Sankpal and Nimbalkar (1979). in Sugarcane affected by Smut, Hwang _et_. _al_., (1983) in Barley affected by _erysiphae_, Santra (1983) in Potato infected by _Synechytrichum_, Dhumal and Nimbalkar (1983) in GSD affected sugarcane have reported high accumulation of starch in infected leaves, and also Nagaraja and Thite (1988) an Nagaraja (1990) reported increase in starch and total carbohydrates in _Rubia_ and _Phyllanthus_ _emblica_ after infection.

Our results of the present investigation are depicted in Table No.(4). There is increase in starch content and total carbohydrate content in infected turmeric leaves. Increasing pattern of starch content and total carbohydrate content is somewhat similar in all varieties of turmeric. Thus this increased content of starch may not be normally utilized for the growth of pathogen hence it accumulates in the infected parts. Thus our results are also showing similar trends like other workers.

(g) **Protein**

Protein are generally correlated with nitrogen contents. Therefore high nitrogen content in the infected leaves ultimately show high protein content. Increase in protein is due to protein synthesis of the pathogen or host Staples and Ledbetter, (1958), on the other hand stimulated protein synthesis in host tissue around the infection centre also observed in the

Table No. 4 : Carbohydrates and protein contents in healthy and infected leaves of turmeric varieties, Salem, Rajapuri and Krishna.

Sr. No.	Parameters	Salem			Rajapuri		Krishna	
		Healthy	Infected by blotch	Infected by spot	Healthy	Infected by blotch	Healthy	Infected by blotch
1.	Carbohydrates							
	a) Reducing sugars	40	76	44	68	96	60	80
	b) Non-reducing sugars	398	86	70	430	126	468	184
	c) Total sugars	438	162	114	498	222	528	264
	d) Starch	2700	4800	4200	4500	6600	2100	3300
	e) Total carbohydrates	3138	4962	4314	4998	6822	2628	3564
2.	Total soluble Proteins	2.83	5.10	3.21	2.64	3.46	2.25	3.08

* Values of carbohydrates are expressed in mg 100^{-1} g dry weight.

* Values of protein are expressed in g 100^{-1} g fresh weight.

infected potato by phytoptthora and infected sweet potato by Ceratocystis (Goodman et al.,(1967). Vidhyasekan et al.,(1973) have shown that their is an increase in protein content of rice grain due to infection of Helminthosporium. Vidhyasekaran and Durairaj (1971) observed similar increase in protein content in citrus due to Xanthomonas infection. Patel and Vaishav (1986) also reported increase in protein in rust infected leaves of groundnut.

Our results shown in Table No.(4) which shows increase in protein content due to infection of Colletotrichum and Taphrina. In Salem variety maximum protein content is observed after infection of colletotrichum as compared to other varieties and Taphrina infection. This increase in protein may be due to synthesis of proteins by pathogen in the host tissue because plenty amino acids are available in the break down of proteins in host cells.

(E) ENZYMES

(i) **Nitrate Reductase**

Nitrate reductase is chloroplastic enzyme and is dependent on photosynthetic electron transfer for ferredoxin which is used as a reductant. This enzyme is all important enzyme for incerporation of Nitrates into amino acids. This enzyme is Molybdoflavoprotein and requires the energy in the form of NADH or NADPH for its activity. Many external and internal factors such as the content of nitrate, availabilitty of reducing power etc., affect the nitrate reductase activity.

Mitra *et al.*, (1978) have reported decreased activity of Nitrate reductase in MLO infected brinjal leaves. Recently Anandakumar (1982) has correlated photosynthetic rate with nitrate reductase and leaf nitrogen in tobacco.

Our results of the present investigation are depicted in Table No. (5) which show decrease in enzyme activity in infected leaves of all turmeric varieties. The maximum decrease was observed in Salem variety infected by *Taphrina* as compared with infection of *Colletotrichum*. Thus decrease in activity of nitrate reductase may be due to decrease in Chlorophylls and carotenoid content and decrease in photosynthetic rate of infected leaves of turmeric.

(ii) **Acid - phosphatase**

This enzyme is hydrolytic enzyme which brings about the break down of phosphate rich compounds such as sugar phosphate, phosphomonoesters etc., (Deo Leo and Sachor, 1970).

Many workers have studied the activity of this enzyme under pathogenicity. Atkinson and Shaw (1955) in Barley infected with powdery mildew, Pitt and Combs (1969) in *Solanum tuberosum* infected with *Phytopthora infestans*, Rai *et al.*, (1979) in *Brassica Juncae* infected with *Microphomia*, *Phasartime* and *Sclerotinia sclerotionum*. Kulkarni (1978) in mango infected with

Capnodium ramosum, Patil (1980) in sunflower affected witth rust; Karande (1984) in Bajara infected with downy mildew fungus, Atkinson and Shaw (1955) in wheat, affected with powdary mildew all have reported increased activity of this enzyme. Staples and Stabman (1964) reported enhanced activity of isoenzymes of acid phosphatase with rust. While De Leo & Sacher (1970) reported increased activity of acid phosphatase due to fungal infection in Banana. Kumar and Nagaraja (1991) also reported increased activity of acid-phosphatase as a result of infection of cercospora to Ricinus leaves.

Our results of the present investigation depicted in Table No. (5) which show increase in activity of acid phosphatase enzyme in infected leaves of turmeric in all varieties. The maximum increased activity was observed in Rajapuri variety as compared to other two varietties. There was slight differencein activity of this enzyme in the infection of colletotrichum and Taphrina.

Thus increased acitivity of acid phosphatase in turmeric infected by Colletotrichum and Taphrina may lead to metabolic shift in infected parts. Which may lead to more accumulation of phosphorus or phosphorus metabolism.

(iii) **Amylase**

This is one of the most important enzymes of carbohydrate metabolism. It is found in wide variety of plants.

Table No. 5 :

Study of activities of enzymes, Nitrate reductase, Acid phosphatase and Amylase in healthy and infected leaves of turmeric varietes, Salem, Rajapuri and Krishna.

Sr. No.	Parameters	Salem			Rajapuri		Krishna	
		Healthy	Infected by blotch	Infected by spot	Healthy	Infected by blotch	Healthy	Infected by blotch
1.	Nitrate-Reductase	0.25	0.23	0.18	0.14	0.11	0.21	0.19
2.	Acid-phosphatase	12.88	17.16	17.82	16.48	22.48	13.06	19.00
3.	Amylase	0.37	0.39	0.43	0.35	0.42	0.35	0.45

* Values are expressed in $\Delta OD = h^{-} g^{-1}$ fresh material.

It catalyses the hydrolysis of starch resulting into sugars.

Several workers studied this enzyme under pathogenicity. Sinha (1976) reported increase activity of enzyme amylase in pennisetum typhoides affected by greenear disease. Change in the activity of amylase due to infection of various phatogens are also well known. Yarkins (1941), Sanwal (1956), Sinha (1976), Chod (1969), Baskaran and Kandaswamy (1977), Kabi et al., (1979), Sindalar et al., (1980), Dorozhkh et al., (1981), Tayal et al., (1981), have reported increase in the activity of enzyme amylase in infected plant leaves. Recently Achar (1994) reported decrease in amylase activity due to infection.

Our results of the present investigation are depicted in Table No. (5) are found increase in amylase activity in diseased plants in all varieties of turmeric. The maximum increase in activity observed in Krishna variety as compared to other varieties of turmeric. In Salem variety infected by Colletotrichum shows more increase than Taphrina infection. Thus enhanced activitty of enzyme amylase in turmeric infected by colletotrichum and Taphrina may be due to high catabolic activity.

(F) **INORGANIC CONSTITUENTS**

(i) **Sodium**

Sodium is a functional element for all terrestrial plants (Nicholas 1961). Sodium can replace potassium partly. It is an activator of transport ATP-ases in animal and possibly in plants. This monovalent nutrient is required for photosynthesis to decrease the Co_2 assimilation. Brownell and Crossland (1972) reported that C_4 plants reuire Na^+ as an essential nutrient.

The values of sodium content are recorded in Table No. (6) which show the sodium content decreased in infected leaves of Curcuma longa varieties.

Both favourable as well as adverse effects of infection on sodium content have been reported Nambiar and Ramakrishnan (1969) in pigeon pea affected by mosaic virus. Sivaprakasam et al., (1976) in brinjal infected by Verticillum. Kulkarni and Kulkarni (1978); Patil and Kulkarni (1977) in mango, sunflower affected by capnodium and puccinia respectively reported decrease of sodium content in the infected leaves of plants.

On the other hand Sankpal and Nimbalkar (1980), in smutted sugarcane, Singh et al., (1986) in papaver somniferum reported increase of sodium content in infected part of the plants.

In our present investigation the sodium content is decreased in infected leaves of Curcuma longa L. The decrease of sodium content may be due to either destructive changes in host tissue or infection have inhibited the absorbance of sodium.

(ii) Potassium

Potassium is the most important monovalent cation in the tissues for its physiological and biochemical functions. Potassium plays a significant role in stomatal opening and closing. It enhances the translocation of photosynthetis. It may be indirectly promotes the synthesis of various organic compounds such as proteins, sugars and polysaccharides. Potassium has an important role in osmotic regulation. It is highly important in raising disease resistance in many crop plants.

The values of potassium content of the present investigation are recorded in Table No. (6). It clearly shows that potassium content increased in infected leaves of different varieties of *curcuma longa* L. viz. Salem, Rajapuri and Krishna.

Fungal pathogen also influences the potassium content of the host. Balasubramanian (1975) in Sorghum infected by *sclerospora* sivaprakasam *et al*., (1976) and Srinivasan and Chelliah (1979) in *solanum melongena* infected by little leaf disease. Ahamad *et al*., (1982) in barley infected with brown rust, Singh *et al*., (1986) in otim infected by downy mildew. Nagaraja and Killedar (1996) in *murraya coenigii* affected by *colletotrichum*, have reported high accumulation of potassium in infected leaves.

On other hand Sivaprakasam *et al*., (1974) in brinjal infected by verticillium Patil and Kulkarni (1977) in sunflower affected by puccinia and Sankpal and Nimbalkar (1980) in smutted sugarcane reported the decrease in potassium content in infected part of the plant.

In our present investigation it was noted that potassium increased in infected leaves of *Curcuma longa* L. varieties viz. Salem, Rajapuri and Krishna. High potassium content in Rajapuri was observed in healthy and diseased leaves.

Grunberg (1958) and Lal *et al.*, (1970) have reported the greater mobility of potassium and its tendency to accumulate at the metabolically active sites. Some antagonistic effects and disturbed ratios of mineral elements cause excessive accumulation potassium in diseased tissue. It has also been stated that both potassium and phosphorus are readily and preferentially transported from healthy to infected tissue and get accumulated there. (Yarwood and Jacobson (1955)) and Roberts and Jensen (1970). Our results of the present investigation show the similar trends of accumulation of potassium in the infected leaves of turmeric varieties viz. Salem, Rajapuri and Krishna. The ratio K/Na also greatly increased because of increased K and decreased sodium in the infected leaves of turmeric varieties.

(iii) Calcium (Ca^{++})

Calcium is an important and essential cation required by the plants. Its optimum value for terrestrial plants is about

0.5% or 125 mole per gram of dry tissue (Epstein 1972). Calcium is of fundamental importance for membrane permeability and maintenance of cell integrity. It has also a role to play in ion uptake. Calcium is required for cell elongation and cell-division (Burstrom 1968). It plays a role in retarding senescence.

Calcium content values are given in Table No. (6). It is observed that the infected leaves contained higher concentration of calcium.

Higher concentration of calcium have been reported by Sivaprakasam et. al., (1974) in brinjal infected by Verticillium, Balasubramanian (1975) in Sorghum affected by downy mildew. Patil and Kulkarni (1977) in Sunflower affected by puccinia. Similarly higher calcium was reported by Sankpal and Nimbalkar (1980), Ghorpade and Joshi (1981) in smutted sugarcane and sugarcane mosaic virus. Nagaraja and Killedar (1996) in Murrya koenigii infected by Colletotrichum gloeosperioides. Singh et al., (1986) in opium affected by downy mildew.

On the other hand low calcium content has been reported by Kulkarni and Kulkarni (1978) in Mango infected by capnodium and Misra and Padhi (1981) in pearlmillet infected with downy mildew.

Our results of the present investigation are similar to the other workers. Increased calcium content is recorded in infected leaves of Curcuma longa L. The possible involvement of calcium in disease resistance was indicated by Walter (1967), Kiraly and Gilly (1976) have confirmed the vital role of calcium in disease resistance aganst fungal infection. Balasubramanian (1981) reported that increased calcium content includes leaf chlorosis in downy mildew affected plants. In infected Curcuma longa L. leaves disturbed calcium metabolism may have similar effects.

(iv) **Magnesium (Mg^{++})**

Magnesium is an essential constituent of chlorophyll and is also associated with many of plant proteins. Magnesium is a cofactor in almost all enzymes that activating phosphorylation process. Magnesium is generally taken up by the plants in lower quantities than calcium.

An increased Magnesium content has been reported by Balasubramanian (1975) in Jawar affected by downy mildew. Hegde and Karande (1978) in Bajara affected by downy mildew, Sankpal and Nimbalkar (1980) in smutted sugarcane. Singh et al., (1986) and Nagaraja and Killedar (1996) in Opium and Murraya koenigii affected by colletotrichum and downy mildew respectively. While Misra and Padhi (1981) in ipomoea affected by white rust have recorded low concentration of magnesium in affected plant leaves.

The results of our investigation are depicted in Table

Table No.6 : Sodium, potassium K/Na, Calcium and Magnesium contents in healthy and infected leaves of turmeric varieties viz. Salem, Rajapuri and Krishna.

Sr. No.	Parameters	Salem			Rajapuri		Krishna	
		Healthy	Infected by blotch	Infected by spot	Healthy	Infected by blotch	Healthy	Infected by blotch
1.	Sodium	0.50	0.41	0.38	0.38	0.31	0.33	0.32
2.	Potassium	3.95	4.84	4.41	6.01	6.01	3.80	4.64
3.	K/Na Ratio	7.9	11.80	11.60	15.81	19.38	11.51	14.50
4.	Calcium	3.66	4.11	4.42	3.68	4.24	3.40	3.60
5.	Magnesium	1.78	1.84	1.86	1.50	1.87	1.50	1.72

* Values are expressed in g 100^{-1} g dry weight.

No. (6) which show increased magnesium content in all infected varieties of turmeric. The maximum concentration was observed in Salem variety as compared to other varieties. Increase in magnesium content may be due to the greater potassium content of infected Curcuma longa leaves. Accumulation of magnesium in susceptible line during initial stage of growth. Seaker et al., (1982) have reported its role in disease resistance. They concluded that magnesium deficient plant have greater concentration of pathogen.

(v) **Nitrogen**

The nitrogen forms the integral and occult part of all constituents. Like Carbon sucrose, nitrogen is also used both for functional as well as structural purposes by Fungi. Again the amount of nitrogen determines the degree of suceptibility. The optimum concentration of nitrogen in glycophytes is 1.5% on dry weight basis (Epstein 1972).

Many workers reported increase or decrease in nitrogen content in infected leaves. Mathur and Vidhyasekaran (1978) in sunflower infected with rust. Sankpal and Nimbalkar (1980) in sugarcane with smut and Goodmen et al., (1967) have reported increased total nitrogen content. Hare (1966) suggested that low nitrogen content may help in developing disease resistance by limiting the synthesis of amino acids and enzyme needed by the pathogen. Nagaraja (1990) in phyllanthus affected by Ravenellia observed increase total nitrogen in infected leaves.

On the other hand Vidhyasekaran and Parambaramani (1971) observed decrease of total protein, amino acid and nitrogen in mango, guava and sapota leaves. Singh and Verma (1973), Ghorpade and Joshi (1981), Dhumal and Nimbalkar (1982) have also reported decreased nitrogen content in infected parts of plants.

Our results of present investigation given in Table No.(7). It clearly shows increased value of nitrogen content in affected leaves of all turmeric varieties viz. Salem, Rajapuri and Krishna. Nitrogen plays an important role in disease resistance. According to Vidhyasekaran and Kandaswamy (1971) and Rao et al., (1978) show increased nitrogen content causes an increase in protein content which adversely affects the concentration of phenols. Thus increased content of nitrogen in infected leaves of turmeric causes more protein contents. These proteins (enzymes) may be newly synthesised by Pathogen for its own metabolic activities and development.

(vi) Phosphorus

Phosphorus concentration of the terrestrial plants is 0.2% of dry weight (Epstein 1972). It is one of the important plant nutrients constituent of phospholipids in the cell-wall and other cell-membranes, sugar phosphatase and adenylate compound like ATP, ADP and AMP. Phosphorus is also a constituents of a variety of organic compound which are essential for the structure and metabolism of plants. Hall and Baker (1972) have shown that inorganic phosphorus plays a vital role in phloem transport. Phosphorus is major element which plays an important role in productivity and hence it is essential ingradient of N.P.K. Fertilizer.

The values of phosphorus content are given in Table No.(7). It shows increased phosphorus content in infected leaves of all the three varieties of Curcuma longa L. viz. Salem, Rajapuri and Krishna.

Increased phosphorus in infected plants have been reported by some workers viz. Weste et al., (1980) in Isopugon ceratophyllus infected by phytophthora. Balasubramanian (1981) in sorghum affected by downy mildew. Chattopadhyay and Bera (1981), Ayres (1981), Nagaraja and Killedar (1996) in rice, barley, murraya, koenigii affected by Helmintthosporium, Erysiphae and Colletotrichum-respectively have suggested an accumulation of phosphorus in the diseased plant: leaves.

On the other hand Patil and Kulkarni (1977) in sunflower infected by rust, Kapur ett al., (1978) in date palm and Sankpal and Nimbalkar (1980) in smutted sugarcane observed decreased phosphorus content in infected leaves.

In our present investigation the phosphorus content is highly increased in infeced leaves of Curcuma longa L. Rajapuri variety shows high amount of phosphorus contentt in infected leaves. Several reasons have been attributted to the increased level of phosphorus in infected leaves. Yarwood and Jacobson (1955), Shaw (1963), Hare (1966) have attributed this increases to tte pathogen induced sinks in host tissue which accumulates greater quantities of phosphorus during pathogenesis. Balsubramanian (1973), Massaux et al., (1977) Kapur et al., (1982) Bhaskaran and Ramnathan (1983), noted that increased phosphorus content increases the disease incidence by rendering the host more succeptible to the invading pathogen in this context. The greater content of phosphorus responsible for its greater succeptibility to leaf blotch disease than Salem.

(vii) Manganese (Mn^{++})

Manganese is generally required in minutes and peripheral traces. Sadasivan (1967) have shown that manganese can act as an ion antagonist against copper and zinc. Manganese is known to effect the cellular concentraion as well as acivity of various enzymes.

Very scanty liturature is available regarding the manganese content. Kulkarni and kulkarni (1978) in mango infected by capnodium. Hegde and Munjal (1971) in Bean pods infected witth Colletotrichum, Sankpal and Nimbalkar (1970) in smuttted sugarcane, Ghorpade and Joshi (1981) in G.S.D. affected sugarcane all have reported decrease in Manganese content, while Patil and Kulkarni (1977), Philip and Devadath (1981) in sunflower, rice affected by puccinia and bacterial blight, recorded increase of manganese content in affected plant leaves.

The result of our present investigation depicted in Table No. (7). It shows decrease of manganese content in all the infected varieties of turmeric. The maximum decrease was observed in Rajapuri variety. The decrease of manganese may also be responsible for lowering the yield and the quality of product.

(viii) Iron (Fe^{++})

Iron forms an integral part of the fungal protoplasm. It is an electron carrier in the oxidation reduction of respiration and is a constituent of certain enzyme and association of iron with various enzymes including cytochromes, cytochrome oxidase, catalase and have lent so much support to the possible role of iron. Its optimum concentration in glycophytes is 2.0 mole per gram of dry tissue (Epstein 1972). While Ramkrishnarao and Ramalingaswamy (1981) noted a range from 127.20 to 270.6 p.p.m. in crop plant.

Many workers have noted that increase or decreased content of iron under pathogenesis e.g. Hegde and Munjal (1971) reported in Bean pods infected with colletotrichum. Patil and Kulkarni (1977), Kulkarni and Kulkarni (1978) also noted that there is accumulation of iron in leaves of sunflower infected with puccinia and mango infected by capnodium respectively. Philip and Devadath (1981) in rice infected with bacterial blight reported increase in iron content as compared to healthy ones.

On the contrary Sankpal and Nimbalkar (1980), Dhumal and Nimbalkar (1982), Mogle and Mayee (1981) in sugarcane with smut, G.S.D. with sugarcane, bajara infected by sclerospora graminicola reported decrease iron content in infected leaves respectively.

In our present investigation Table No. (7) shows there is decrease in iron content in infected leaves of Salem and Rajapuri varieties. But there is no change in iron content in healthy and infected leaves of Krishna variety. The maximum decrease in iron content was observed in leaf blotch of Salem variety. Thus decrease in iron content may be due to its translocation to physiolgoically active site as reported by Brown (1976).

(ix) **Copper (Cu^{++})**

The concentration of copper in plants is generally low (Longeragan 1975). According to Epstein (1972) the optimum value of it in terrestrial plants is 0.10 mole per gram of dry tissue or 6 p.p.m.

The work of Ramkrishnarao and Ramlingaswamy (1981) indicated that the copper concentration depends on the growth phase of sugarcane crop. The available reports indicate that Fungal disease cause an increase in copper content of host plant. Betz et al., (1980) and Balasubramanian (1981) noted increased copper content in the leaves of cabbage and sorghum infected by plasmodiophora and sclerospora respectively.

The values of copper depicted in Table No. (7) show the increase in copper content in infected leaves of all turmeric varieties. The maximum increase was observed in Rajapuri variety after infection. In Salem variety inreasing pattern of copper content is same in both diseases. This increase in copper content after infection may due to the requirement of copper for the growth of pathogen in host tissue.

(x) Zinc (Zn^{++})

Zinc is a microelement and required in trace amount of plants its optimum concentration for terrestrial plants is 0.3 mole/g dry tissue or 20 p.p.m. (Epstein 1972).

Vijaya Rao et al., (1967), Singh et al., (1970) Deshmukh and Mayee (1978) and Misra et al., (1981) have reported that zinc plays an important role in disease resistance. They have noted that an application of zinc decreases the cncentration of viral and fungal pathogens and increases the disease resistance in host tissue by lowering the disease incidence while Wutscher and Hardesty (1979) and Shevchenko et al., (1980) are of the opinion that trace element like zinc increases the disease resistance by increasing the phenolic content which there by checks the growth of invaded pathogen. Prasad (1979) reported that increased zinc content alters host metabolism and checks the symptoms produced by Fusarium.

The values of zinc content are given in Table No. (7)

which show decrease in Zn content in all infected varieties of turmeric. The maximum decrease was observed in Salem variety. Infection by colletotrichum and Taphrina show somewhat same pattern in Zinc content after infection. The decrease in Zinc content may adversely affect the decrease resistant capacity of host plant against pathogen.

Table No. 7 : Nitrogen, Phosphorus, Manganese, Iron, Copper and Zinc contents in healthy and infected leaves of turmeric varieties, Salem, Rajapuri and Krishna.

Sr. No.	Parameters	Salem			Rajapuri		Krishna	
		Healthy	Infected by blotch	Infected by spot	Healthy	Infected by blotch	Healthy	Infected by blotch
1.	Nitrogen	0.45	0.81	0.51	0.42	0.55	0.35	0.49
2.	Phosphorus	0.12	0.14	0.16	0.13	0.17	0.11	0.14
3.	Manganese	0.13	0.036	0.08	0.084	0.04	0.06	0.036
4.	Iron	0.06	0.02	0.05	0.04	0.02	0.03	0.02
5.	Copper	0.08	0.10	0.10	0.07	0.10	0.07	0.08
6.	Zinc	0.20	0.11	0.13	0.10	0.09	0.07	0.06

* Values are expressed in g 100^{-1} g dry weight.