CHAPTER-III

RESULTS AND DISCUSSION

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A) Water Stress Studies :

The two safflower varieties, Local and JLSF-88, were cultivated upto the heading stage and then water stress was given for four and eight days. The results are recorded in Table 4,5 and 6 and phenotypic results are shown in Figure 2,3 and 4. The various physiological aspects are discussed below :

a) Effect of water stress on growth parameters :

The results are depicted in Table 4. It appears from the results that both varieties affected by water stress as compared to the watered plants as control (Figure 2 and 3). The average plant height decreased slightly. In both Local variety and JLSF-88 the shoot length decreased with increasing water stress period. The effects are more significant in JLSF-88 than the Local variety. The root length is increased more remarkably, in Local variety than JLSF-88, with increasing water stress period. The shoot: root ratio decreased considerably in stress conditions. There are many reports which suggest that generally water deficits reduce the plant growth (Loomis, 1934; Thut and Loomis, 1944; Richards and Wadleigh, 1952). According to Itai and Benzioni (1976) water stress may affect growth by reducing biosynthetic processes and enhancing catabolism.

Fig. 1 Habit of two safflower (Carthamus tinctorius, L.) varieties viz.

1) Left side - Local variety
2) Right side- JLSF - 88.

Fig. 2 Effect of water stress on Local, safflower (*Carthamus tinctorius*, L.) variety.

1) Control (LC)
2) 4 days water stress (L-W4)
3) 8 days water stress (L-W8)

Fig. 3 Effect of water stress on JLSF - 88, safflower (*Carthamus tinctorius*, L.) variety.

1) Control (J.C)
2) 4 days water stress (J-W4)
3) 8 days water stress (J-W8)

Fig. 6 Effect of NaCl treatment on the Local, safflower (Carthamus tinctorius, L.) variety.
1) Control 2) 0.025% NaCl treatment 3) 0.05% NaCl treatment 4) 0.1% NaCl treatment 5) 0.2% NaCl treatment 6) 0.4% NaCl treatment.

Fig. 7 Effect of NaCl treatment on the JLSF - 88, safflower (Carthamus tinctorius, L.) variety.
1) Control 2) 0.025% NaCl treatment 3) 0.05% NaCl treatment 4) 0.1% NaCl treatment 5) 0.2% NaCl treatment 6) 0.4% NaCl treatment.

Table 4 : Effect of water stress on the growth parameters in two safflower (*Carthamus tinctorius*, L.) varieties.

Parameters	Local			JLSF-88		
	Control	Water stress		Control	Water stress	
		4-days	8-days		4-days	8-days
Average root length per plant (cm)	10.3	12.2 (+18.45)	12.8 (+24.27)	11.9	12.90 (+11.68)	13.30 (+11.76)
Average shoot length per plant (cm)	50.4	44.87 (-10.97)	41.90 (-16.86)	55.50	48.04 (-13.44)	41.60 (-25.04)
Average plant height (cm)	60.7	56.07 (- 7.63)	54.7 (-9.88)	67.4	60.14 (-10.77)	54.90 (-18.55)
Shoot/root	4.89	3.68 (-24.74)	3.27 (-33.13)	4.66	3.97 (-33.37)	3.13 (-37.92)
Average Leaf thickness (mm)	0.036	0.030 (-16.67)	0.020 (-44.44)	0.036	0.031 (-13.89)	0.022 (-38.89)
Average Leaf area (cm^2)	7.65	6.52 (-14.77)	4.09 (-46.54)	8.26	7.15 (-13.44)	6.02 (-27.12)

Values in bracket indicate per cent decrease (-) or increase (+) over control.

The similar results were observed in wild safflower, ecotype Carthamus tinctorius, Bieb by Bassiri et al., (1977). Gupta et. al., (1985) have reported that increased in soil moisture stress caused more depression of safflower root growth than shoot growth which indicated by a linear increase in shoot:root ratio. The relative plant height remains unaffected upto -3 bars soil moisture stress and then decline rapidly. In the present investigation the decline is more slowly in JLSF-88 than the Local variety. The increase in root length with increased water stress in both varieties is a sign of drought resistant mechanism. The similar results were recorded by Jarvis and Jarvis (1963). Magdum (1985) also show similar increase in root length when sunflower plants were subjected to water stress. From our results it appears that growth pattern in JLSF-88 is affected more than the Local variety due to the water stress.

The effect of water stress on leaf thickness and leaf area is presented in Table 4. In the present investigation leaf thickness in both varieties decreased with increasing water stress period. The percentage of decrease is more in Local variety by both four and eight days water stress than JLSF-88, however the leaf area in JLSF-88 suffered less than the Local variety with increasing water stress period. Both leaf area and leaf thickness are decreased in Local variety by 15 % at four days water stress period but later on it reaches upto 44-46 % by eight days water stress period. These results indicate that prolonged water stress adversely affects the leaf morphology which may reduce photosynthetic rate. The similar results were recorded in JLSF-88 with leaf thickness. But leaf area in JLSF-88 decreased slightly with four and eight days water stress. According to Schratzs (1931), in a small leaved xerophyte Covillea tridentata, the leaf area and leaf thickness both affected considerably under water stress conditions as compared to control. In sunflower, due to water stress leaf area is reduced (Yegappen and Paton, 1982). The decreased leaf area and leaf thickness is because of increased drying process with water stress period and also due to loss of moisture. This is an adaptive feature to drought conditions.

b) Effect of water stress on organic constituents :

i) Effect of water stress on the moisture and R.W.C.

The results depicted in Table 5 show that the moisture is reduced in both Local variety and JLSF-88 under water stress over the control plants. The Local variety retained more moisture under such condition than JLSF-88. The decline in moisture with increasing water stress period is common in both safflower varieties. Decrease in the moisture content from leaves affects many processes of the plant. According to Levitt (1956) the loss of water is the initial step, in water deficit plants, occurring due to the dehydration of protoplasm. Loss in moisture during the water deficit condition induces heat tolerance not only in

Table 5 : Effect of water stress on the moisture, R.W.C. and organic constituents in the leaves of two safflower (*Carthamus tinctorius*, L.) varieties.

Organic Constituents	Local variety			Var. JLSF-88		
	Control	Water stress 4-days	Water stress 8-days	Control	Water stress 4-days	Water stress 8-days
Moisture %	50.46	35.00 (-30.64)	32.15 (-36.34)	60.00	40.00 (-33.37)	37.25 (-37.92)
R.W.C.	35.64	30.23 (-15.18)	28.13 (-21.07)	62.77	54.06 (-73.88)	53.02 (-15.4)
Ø TAN	40.67	72.01	73.59	46.00	75.08	87.50
+ Polyphenols	1.78	2.25	2.72	1.30	1.60	2.85
* Chlorophyll'a'	98.16	123.56	141.27	94.5	117.11	183.99
*Chlorophyll'b'	95.28	85.92	90.35	74.72	88.26	140.03
* Total chlorophylls	193.38	209.42	231.55	169.17	205.41	323.23
* Chl. 'a' / Chl. 'b'	1.03	1.44	1.56	1.27	1.33	1.31

Ø Values expressed as ml of 0.1 N NaOH required to neutralize the acids present in plant extract of 100 g fresh tissue

+ Values expressed as g 100 g^{-1} fresh tissue

* Values expressed as mg 100 g^{-1} fresh tissue.

Values in bracket indicate percent decrease (-) or increase (+) over control.

lower plants and xerophytic higher plants but also in mesophytic higher plants (Kappen and Lange, 1968). The retention of moisture under drought condition is a drought resistant nature (Chavan, 1980) In the present investigation, the water retention occurs in both, Local variety and JLSF-88, which show their drought resistant nature.

The values of RWC (Relative Water Content) are recorded in Table 5. In the present investigation both the Local variety and JLSF-88 varieties show decrease in RWC by 13 - 21 % over control. It is a measure of dehydration avoidance. The values decline in both four and eight days water stress. It is more remarkable in Local variety than JLSF-88. RWC is used a measurement criterion for drought resistance (Walter's, 1963). From our results it appears that JLSF-88 is a drought resistant variety.

ii) Effect of water stress on Titratable Acid Number (TAN):

Generally water stress develop many adaptations in plant. These adaptations favour the conservation of water by developing succulance due to the accumulation of organic acids and water. In the present investigation (Table 5) both Local variety and JLSF-88 show remarkable increase in titratable acid number due to the water stress. But even though the period of water stress increased the respective increase in titratable acid number is not significant. The phenomenon of increase in TAN is common in succulent plants under water stress condition, however, it was also reported in some non-succulent plants like Salvadora persica and Prosopis juliflora (Gaur, 1968). The present investigation shows a drought resistant mechanism in safflower particularly more in JLSF-88 than Local variety.

iii) Effect of water stress on Polyphenols :

Polyphenols are commonly known as tannins. They take part in growth metabolism and act like phytoharmones. From the present investigation (Table 5) it appears that both safflower varieties show accumulation of polyphenols with increasing water stress period, however the pattern of accumulation of polyphenols is different. In the Local variety, polyphenols accumulated with increasing period of water stress. But in JLSF-88 there is a sudden increase in polyphenol accumulation with eight days water stress. The accumulation of polyphenols is one of the drought resistant criteria. Talha et al., (1975) have shown that increase in alkaloid content in Catharanthus roseus due to the water stress condition. The tannin accumulation observed in Impatiens balasmica under water stress condition (Todd et al., 1974). But sometimes drought may decline the polyphenol content (Magdum, 1984). Our results show that the Local variety and JLSF-88 develop drought resistance under water stress period by increasing the polyphenols.

iv) Effect of water stress on chlorophylls :

The chlorophylls in two safflower varieties are depicted in Table 5. The total chlorophylls are accumulated in both varieties with increasing water stress period. The accumulation of chlorophyll 'a' over control during water stress period is observed in both varieties. In JLSF-88 values for chlorophyll 'a' are higher due to water stress than the Local variety. While chlorophyll 'b' in these varieties show different behaviour. The Local variety loose the chlorophyll 'b' content due to the water stress. While JLSF-88 show same pattern as observed in chlorophyll 'a' Eventhough Local variety exhibit different behaviour with chlorophyll 'a' and 'b', the total chlorophylls increased due to the water stress period in both the varieties. The values of total chlorophylls in JLSF-88 are higher than the Local variety. The ratio of chlorophyll 'a': 'b' is increased due to water stress in both varieties.

There are different views regarding the response of chlorophylls to water stress period. Downey (1971) has shown the increase in the chlorophyll content under the water stress. Hollam and Luff (1980) have reported the accumulation of chlorophylls in Xerophyte villosa during desiccation. Kushnirenko et al., (1971) have shown that the accumulation of chlorophylls under water stress condition is a drought resistant capacity of plant. The safflower varieties in the present investigation show such drought resistant mechanism. Nalawade (1983) also found similar results in <u>Guizotia abyssinica</u>. Our results of chlorophyll 'b' content in Local variety are similar to that observed in safflower variety - Tara grown under water stress conditions (Sawant, 1983). Albert et al., (1975) have reported the similar accumulation of chlorophyll 'b' due to the water stress.

c) Effect of water stress on inorganic constituents :

In plants the inorganic elements play an important role in plant metabolism. They required by plant for their different functions. The relative concentration either excess or deficit in plant ulters their growth pattern. The leaf is an ideal plant organ which shows major metabolic processes (Lagatu and Maume, 1934). The results of the effect of water stress on different inorganic elements in the leaves of two safflower varieties are depicted in Table 6 and discussed below.

1) Sodium :

The values for sodium in the leaves of two safflower varieties range between 0.9 % to 1.4 % dry wt.(Table 6). Local variety shows increase in sodium content initially under water stress, while further increase in water stress condition decreases the sodium, however JLSF-88 shows progressive decline in sodium level with increasing water stress.

Table 6 : Effect of water stress on inorganic constituents in the leaves of two safflower (Carthomus tinctorius, L.) varieties.

Inorganic elements	LOCAL			JLSF - 88		
	Control	Water stress		Control	Water Stress	
		4-days	8-days		4-days	8-days
Na^{+}	1.1	1.80	0.9	1.425	1.25	1.15
K^{+}	1.7	1.3	1.2	2.2	2.15	2.05
K^{+}/Na^{+}	1.545	1.21	1.33	1.54	1.72	1.78
Ca^{2+}	5.1	3.05	2.25	2.9	2.8	2.6
K^{+}/Ca^{2+}	0.0333	0.042	0.053	0.075	0.076	0.078
Mg^{2+}	1.40	0.93	0.69	0.70	0.67	0.65
Fe^{3+}	0.56	0.60	0.53	0.48	0.53	0.53
Cu^{2+}	0.1315	0.1334	0.1306	0.1230	0.1245	0.1255
Zn^{2+}	0.24	0.26	0.11	0.16	0.11	0.10
Mn^{2+}	0.024	0.021	0.019	0.021	0.022	0.021
Cl^{-}	1.8992	1.6401	1.5087	1.8637	1.1306	0.9762

Values expressed in g 100 g^{-1} dry tissue.

The role of sodium in water stress was explained by many workers. Epstein (1972) has reported that accumulation of sodium in water deficit condition decrease plant wilting by maintaining adequate osmotic pressure to influence water balance. Werkhoven et al., (1966) has shown that increasing sodium upto 30% resulted in increase in yield and seed oil. Pozuela and Felipe (1972) reported the absorption and translocation of sodium in safflower. Generally oil seed crops show low amount of sodium in the leaves e.g. *Arachis hypogea* 0.08 % (Karadge and Chavan, 1981) and *Guizotia abyssinica* 0.06 % (Nalawade, 1983). But safflower leaves show comparatively higher amount of sodium which range between 1.00 % to 1.4 % dry wt. The sodium content decreases due to the water stress except in Local variety where four days water stress show accumulation of sodium. Rahman et.al., (1971) have shown the accumulation of sodium under water stress condition is due to reduction in dry weight. Takeshi (1966) has found very little difference in sodium content in the leaves of *Brassica rapa* and *Vigna sinensis*.

ii) Potassium :

Potassium is an important element in plant metabolism. It acts as a cofactor in most of the biochemical reactions. In the present investigation potassium estimated in two safflower varieties and found that potassium level in both varieties is adequate which range from 1.2 % to 2.2 % dry wt. (Table 6). Due to the water stress the potassium level decreases. This decline is more remarkable in Local variety than JLSF-88.

The potassium content in safflower was studied by Bisht *et al.*, (1987). According to him potassium deficiency resulted in reduced growth and development and exhibited visible symptoms as brown necrotic spot in the middle of the leaves of safflower. The response of potassium under water stress condition differ from species to species. Morais and Wiersa (1975) have shown that due to water stress potassium content decrease than watered plant. Gujarathi (1984) recorded different behaviour of potassium content in two groundnut varieties grown under water stress, var.JL-24 shows reduced potassium content while var. SB-11 shows first decline and then increased potassium level beyond control level. Kongstrud (1969) and Rahman *et al.*, (1971) recorded that potassium content increased with water stress.

Potassium : Sodium ratio increased with water stress in JLSF-88 and decreased in the Local variety which suggest that JLSF-88 is superior to the Local variety in absorption of potassium over sodium. According to Simonis and Werk (1958), increased potassium : calcium ratio in *Vicia faba* leads to development of drought tolerance. In the present investigation the results show similar increase in potassium: calcium ratio in both varieties indicating their drought tolerant nature.

iii) Calcium :

The results of calcium in safflower varieties are depicted in Table 6. From this it is clear that the Local variety is rich in calcium than JLSF-88. The calcium contents in both varieties are decreased with progressive water stress period. The results are more significant in Local variety than JLSF-88.

The calcium is generally regarded as the most immobile element and deposited in leaves (Ferguson and Bollard, 1976). The calcium content differs with plants. The optimum value for terrestrial plants is 0.5% dry wt. (Epstein, 1972). Karadge and Chavan (1981) have shown that in groundnut varieties calcium is about 5.6 % to 6.0 % dry wt. In the present investigation due to the water stress calcium content decrease. The similar results were obtained by Singh and Singh (1970). The lowering of calcium and increase in potassium : calcium ratio during water stress in tomato was shown by Vander Bon (1973).

iv) Magnesium :

Magnesium content in two safflower varieties are shown in Table 6. Magnesium content in Local variety is higher than JLSF-88. The magnesium content decreased with progressive water stress period however, decrease of magnesium in Local variety is greater than JLSF-88 with respect to their control values. This suggests that JLSF-88 is faily drought resistant as compared to Local variety. Magnesium is a constituent of a chlorophyll molecule, an activator of certain enzymes and an osmotic regulator (Sutcliffe, 1967). The average values for magnesium in terrestrial plants range from 0.05% to 0.79% dry wt.(Ferry and Word, 1959). But the plants need about 0.2% magnesium for the optimum growth (Epstein, 1965). Magnesium deficiency reduces phospholipids, phosphotidyl glycerol and galactosylidighycerides (Kongstrud, 1969). Rehman <u>et al.</u> (1971) have shown the accumulation of magnesium during water stress period. Gujarathi (1984) has reported in groundnut that magnesium content varies with variety and period of water deficit.

v) <u>Iron</u> :

The iron content of the two safflower varieties are recorded in Table 6. From this it is clear that the iron content increase with progressive water stress. The iron content is higher in Local variety than JLSF-88. The prolonged water stress reduced iron content over control in Local variety, while in JLSF-88 the iron content increased and remain constant under progressive water stress period.

As far as iron is concerned it plays an important role in chlorophyll synthesis, ferredoxin synthesis, controlling activity of ribulose diphosphate carboxylase, the rate of carbon assimilation in sugar phosphates and sucrose formation etc. (Ralph, 1975). Sangale <u>et al.</u> (1981)

have shown that spraying of iron in the form of 0.4% ferrous sulphate with 0.2% borax and 0.5% zinc sulphate increased yield in safflower considerably. From our results it appears that both safflower varieties accumulated sufficient iron. The iron values for land plants are 0.011 % dry wt. (Epstein, 1972). In the present investigation both safflower varieties show a correlation between the accumulation of iron and chlorophyll with water stress period.

vi) Copper :

The results of copper in two safflower varieties are shown in Table 6. The copper content increased slightly with progressive water stress period like iron. Copper in Local variety increased slightly and then decreased. On the other hand, JLSF-88 shows increased copper content with increased water stress.

The work on copper content during water stress is scanty. According to Rao and Ramamoorthy (1981) copper level is affected severely due to water stress. Gujarathi (1984) has shown that in two varieties of groundnut the behaviour of copper is different, var. JL-24 shows increased copper level with water stress period while in var. SB-11 the copper level decreased. From the present results it seems that JLSF-88 shows fairly higher copper content than Local variety.

vii) Zinc :

The results of zinc content are recorded in Table 6. The zinc content also exhibits same pattern as that of iron and copper in Local variety i.e. water stress enhanced the zinc content level while JLSF-88 variety show decreased zinc content with increased water stress period.

Zinc is a major micronutrient. In safflower the yield is increased by spraying 0.5% zinc sulphate (Sangale *et al.*, 1981).

viii) Manganese :

The manganese content in the two safflower varieties is depicted in Table 6. Both varieties show different pattern for manganese content in response to water stress. The gradual decrease in manganese content occurred in Local variety. But manganese content in JLSF-88 is not affected severely by prolonged water stress period. The normal value of manganese for growth and development is 0.005% (Stout, 1961). From the present investigation it is clear that manganese is sufficient in both the varieties.

Recently, Lewis and Mcfralane (1986) have shown that the application of manganese significantly increased safflower yield from 1040 to 1050 kg/ha, by increasing number of seeds per plant. The results of present investigation indicate that both varieties maintain manganese level to withstand against stress conditions and increasing drought tolerance capacity.

ix) Chlorides :

The chlorides content is depicted in Table 6. It has been observed that chlorides when present in low concentration, stimulates plant growth. But harmful at higher concentration. In the present investigation, the chloride ion content decreased with increasing water stress period. The loss of chloride ion is much faster in JLSF-88 than the Local variety. The chloride ion shows stimulatory effect on Hill reaction (Izawa et al., 1969). Osmond (1968) has reported that Cl^- content in land plants vary from 1 to 3% of dry tissue, (Ferry and Ward, 1959). Our results show accumulation of 1.8% chlorides in both varieties. But under water stress conditions the amount of chlorides is reduced which probably inhibits the photosynthetic reactions. The variety JLSF-88 reduced considerable chloride than the Local variety under progressive water stress period.

d) Effect of water stress on the activity of enzymes :

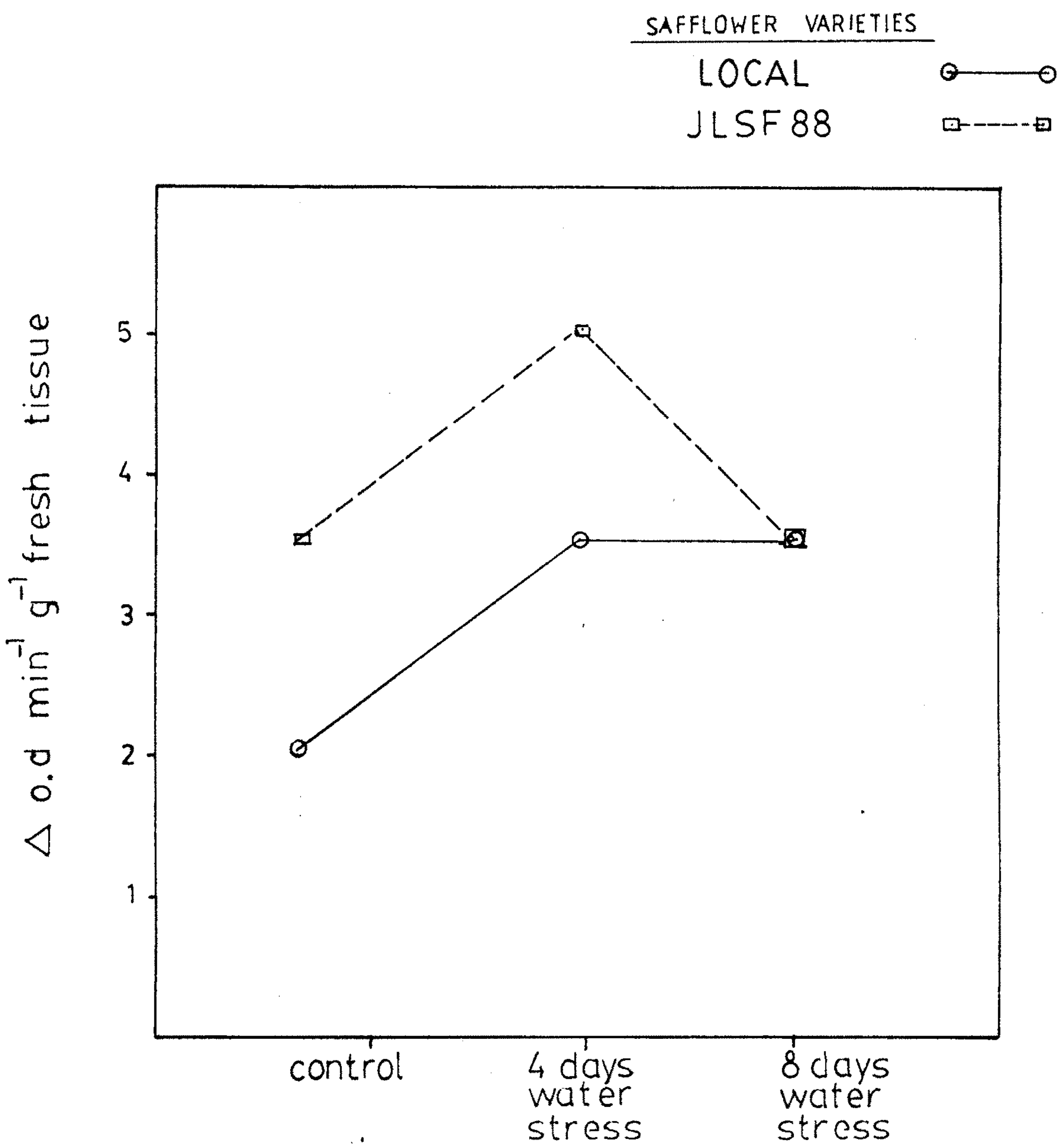
1) Peroxidase : (EC 1.11.1.7)

The enzyme peroxidase is an indicator of respiration rate (Horovits et al., 1968). In the present investigation enzyme peroxidase activity in both safflower varieties is enhanced (Figure 4). In Local variety the activity of peroxidase is increased by 75% over control and remain constant eventhough the water stress period prolonged, while it decreased to control level in JLSF-88.

In safflower the activity of peroxidase in the vegatative tissue was studied by Saito et al., (1986). However there is no report regarding the activity of peroxidase in safflower under water stress condition. The identification and polymorphism of different safflower cultivars and their ecotype on the basis of isozyme pattern was recorded by Bassiri (1977). Peroxidase play an important role in growth

FIG: 4: EFFECT OF WATER STRESS ON THE ACTIVITY OF ENZYME PEROXIDASE IN THE LEAVES OF TWO SAFFLOWER (CORTHAMUS TINCTORIUS, L) VARIETIES.

A/



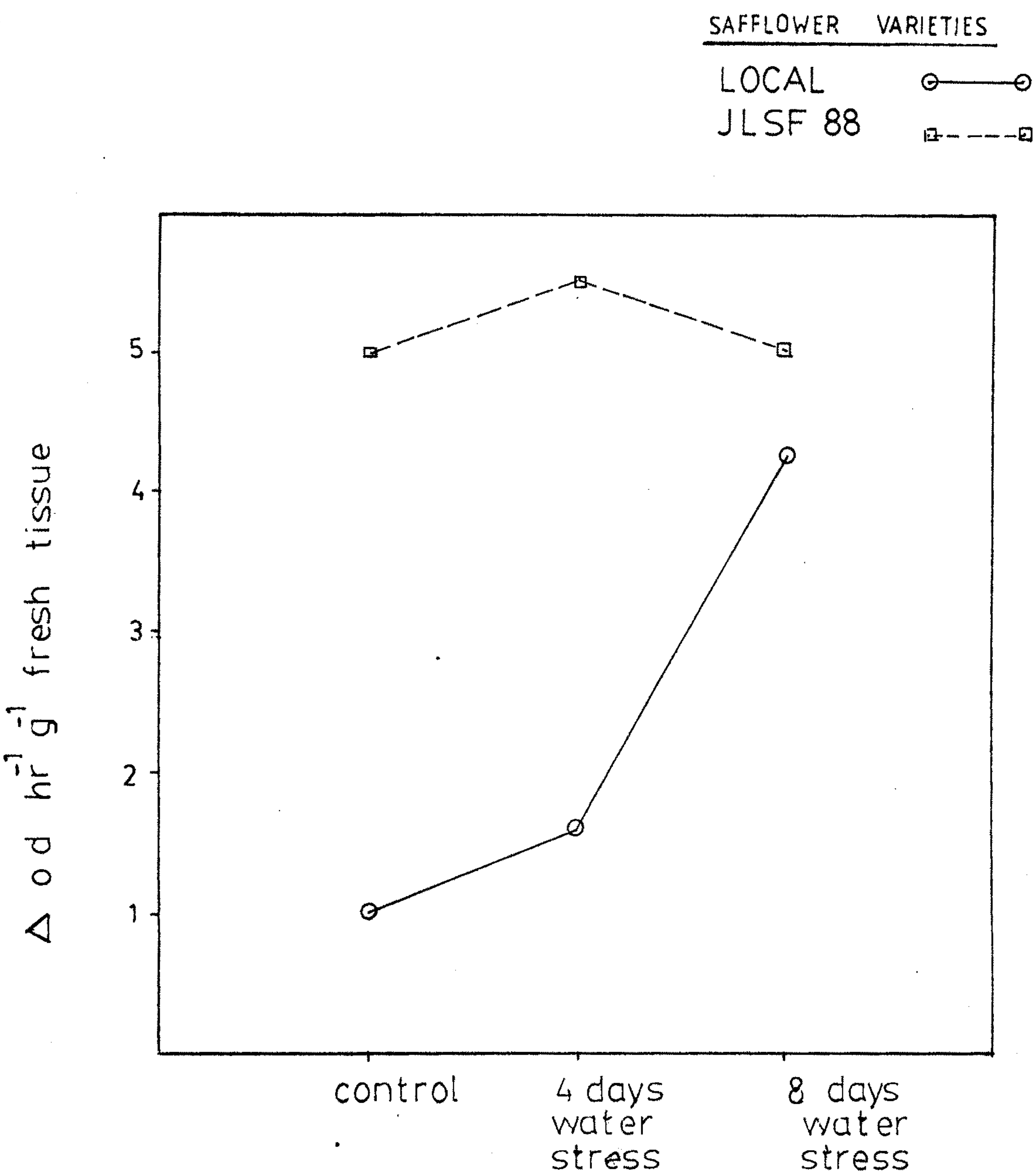
and development by controlling auxin catabolism (Rao, 1962). Generally peroxidase activity decreased due to water stress in wheat (Lukicheva, 1968). According to Stutte and Todd (1969) certain peroxidase bands disappeared and new bands appeared with increasing water stress. Levitt (1972) has shown that peroxidase activity have no definite relationship to soil moisture. But recently Thukral *et al.* (1986) have reported in *Brassica* that peroxidase activity is high under water stress and it is a drought tolerant character. We have also recorded similar results of increased activity of peroxidase.

2) Acid phosphatase : (EC 3.1.3.2.)

The results of the activity of enzyme acid phosphatase is shown in figure 5. From this it appears that in the Local variety the activity of acid phosphatase increased more remarkably under increased water stress conditions than the JLSF-88 where the prolonged water stress period show decrease in the activity.

Bassiri (1977) has determined different types of polymorphic indices (PI) from acid phosphatase for different safflower varieties. The mean PI for the introduced, Local and wild safflower varieties were 0.069, 0.052, 0.058 respectively. Mishra *et al.* (1978) have reported that the germinating rice seeds under drought show decrease in acid phosphatase activity. However, out of five, three cotton

FIG. 5: EFFECT OF WATER STRESS ON THE ACTIVITY OF ENZYME ACID PHOSPHATASE IN THE LEAVES OF TWO SAFFLOWER (CØRTHAMUS TINCTORIUS, L) A/ VARIETIES.



species show considerable increase in acid phosphatase activity under osmotic stress (Vieira-da-Silva,1969 and Gaikwad, 1984). Kandpal and Rao (1982) showed that under water deficit condition the enhanced acid phosphatase activity in ragi, Eleusine corocana while reverse pattern seen in mung bean, Vigna radiata. Kunjamma (1983) has shown the acid phosphatase which slightly altered due to water stress. In the present investigation rise in acid phosphatase indicates a drought resistant nature.

B) Salt Tolerance Studies In Safflower :

Now a days due to extensive use of fertilizers and poor drainage the nature of soil changes. In India about 12 million hectares of land was commonly affected by salinity and alkaline besides the coastal saline soil. One of the most useful strategies to combat soil salinity is to select salt tolerant crop varieties. Although safflower (Carthamus tinctorius, L.) is considered as a salt tolerant crop (Weiss, 1971). The salt tolerance ratings are useful in predicting how one crop or variety might fare relative to one another in saline soils, eventually helping in the management problems of irrigated agriculture (Mass, 1984). Thus, in the present investigation attempts have been made to study salt tolerance of safflower by studying some physiological aspects.

a) <u>Effect of NaCl treatment on growth parameters</u> :

The results of effect of NaCl treatment on two safflower varieties, Local variety and JLSF-88 are depicted in Table 7 and figure 6 and 7. The average plant height in both varieties is adversely affected with progressive NaCl treatment except JLSF-88 which shows enhanced plant height at 0.025 % NaCl treatment. This may be a stimulatory dose of NaCl treatment. The similar results were obtained in average shoot length, which is affected by NaCl treatment, but stimulation is observed at 0.025 % NaCl concentration in JLSF-88 variety. The average root length in both varieties increases with NaCl treatment particularly at 0.025 % and 0.05% NaCl concentrations which are the stimulatory doses for root length in JLSF-88 and Local varieties respectively.

The salt stress, particularly NaCl, have different effects on growth pattern in various plants. Strogonov (1964), Malhotra <u>et al.</u>, (1986) have shown that due to salt treatment cessation of growth is observed. But recently the number of workers have shown the stimulation of growth due to the salt treatment in various plants such as halophytes (Greenway, 1968). Yeo and Flowers (1980) recorded growth stimulation in saline medium due to the enlargement of cell size which accumulate salts in a halophyte, <u>Suaeda maritima</u>. Ahmed <u>et al.</u>, (1979) reported an increase in dry weight in oil

Table 7 : Effect of NaCl treatment on growth parameters of two safflower (*Carthamus tinctorius* L.) varieties.

Parameters	LOCAL variety						Var. JLSF-88					
	Control	NaCl treatment					Control	NaCl treatment				
		0.025%	0.05%	0.1%	0.2%	0.4%		0.025%	0.05%	0.1%	0.2%	0.4%
Average root length per plant(cm)	10.30	9.6	10.95	10.70	10.40	10.00	11.9	15.2	13.6	14.6	12.32	13.56
Average shoot length per plant (cm)	50.40	48.9	44.30	43.30	42.38	41.10	55.5	56.30	51.00	52.20	46.30	50.48
Average plant height (cm)	60.70	58.7	55.25	54.00	52.78	51.10	67.40	71.50	64.60	66.80	58.62	64.04
Shoot/root	4.89	5.09	4.05	4.05	4.08	4.11	4.66	3.70	3.75	3.57	3.75	3.72
Average Leaf thickness (mm)	0.036	0.033	0.034	0.041	0.042	0.045	0.036	0.040	0.042	0.042	0.044	0.040
Average leaf area (cm^2)	7.64	6.62	5.37	5.96	5.00	5.07	8.26	7.15	6.65	6.19	5.41	6.60

producing crops growing under moderate salinity effect. Gaikwad et al., (1985) and Kingshury and Epstein (1986) have shown that salinity had little effect on the growth of salt resistant plants. According to Weiss (1971) and Mehta and Johri (1985) the safflower is considered as highly salt tolerant crop.

The effect of salt stress on the safflower was studied by different workers. Kurian and Iyengar (1972) have reported that safflower grown with sea water reduced plant height, seed yield and 1000 seed weight. Francois and Bernstein (1964) have shown that increasing salinity reduce seed yield by decreasing the number of heads per plant. Janardhan et al., (1986) have recorded that eventhough the number of heads per plant increased due to the salinity, yield is reduced. Kole and Gupta (1982) have shown that at low concentration of NaCl, growth is promoted in safflower however higher NaCl treatment adversely affect plant growth (Ramana and Rama Das, 1978).

The similar results were obtained in the present investigation where shoot length is reduced in both safflower varieties. However the shoot length is enhanced at 0.025 % NaCl concentration in JLSF-88 which indicate the stimulatory effect of NaCl.

The root length in both safflower varieties is increased over control due to the progressive NaCl concentrations. However maximum root length is observed at 0.025% and 0.05% NaCl treatment in JLSF-88 and Local variety respectively. This shows stimulatory effect of NaCl. Kole and Gupta (1982) have shown that shoot:root ratio was promoted at lower NaCl level and it is inhibited considerably at higher concentration of NaCl. The shoot:root ratios decreased considerably over control due to the increasing NaCl concentration in JLSF-88. However the Local variety show slight increase in ratio at 0.025 % NaCl treatment, but then decreased with higher NaCl concentrations. Ramana Rao et al.,(1984) have shown that stimulation by NaCl is because of harmonal imbalance. In the present investigation increase in root length due to salinity is a salt tolerant character observed in JLSF-88 variety.

Salinity or NaCl has a tendency to promote succulance in plants (Keller, 1952). This succulence is resulted due to Na^+ and Cl^- ions (Gale and Poljakoff-Mayber, 1970). Increase in leaf thickness due to the salinity was shown by many workers (Mendoza, 1971; Hegde, 1972; Karadge, 1980 and Karadge et al., 1983). Even mangroves also show leaf succulance due to NaCl treatment (Jamale, 1975). In the present investigation leaf thickness is increased due to higher NaCl concentration in both safflower varieties. However, leaf area decreased due to salinity in both the safflower varieties. The previous records were also showing reduction in leaf area in different plants (Meiri and Poljakoff-Mayber, 1970 and Zakharin et al., 1982). Wignarajah et al., (1975) have shown the reduction in leaf area because of reduction in cell enlargement and cell division.

b) Effect of NaCl treatment on Organic constituents:

i) Moisture and Relative Water Content (RWC):

The results of moisture and RWC are recorded in Table 8. Both safflower varieties show increase in leaf moisture percentage over control due to NaCl treatment. The Local variety show increase in leaf moisture except at 0.025 % and 0.4% NaCl treatment. This bring about the dilution effect and reducing the toxic effects of NaCl treatment.

Kabuzenko and Ponomarova (1976) have recorded decline in moisture in tomato plant under salinity. But Karadge et al., (1983) have observed in *Lippia nodiflora* that leaf moisture percentage decreased at low salinity level but with higher salinity it increased over control. Similar results are recorded in the present investigation in Local variety of safflower.

The result of R.W.C. depicted in Table 8 are showing similar pattern as that of moisture percentage. In JLSF-88

Table 8 : Effect of NaCl treatment on moisture, R.W.C. TAN and polyphenols in the leaves of two safflower (Carthamus tinctorius L.) varieties.

Parameters	LOCAL variety						Var. JLSF-88					
	Control	NaCl treatment					Control	NaCl treatment				
		0.025%	0.05%	0.1%	0.2%	0.4%		0.025%	0.05%	0.1%	0.2%	0.4%
Moisture %	50.46	36.22	60.00	68.79	63.34	48.44	60.00	71.36	63.21	66.58	64.92	64.34
R.W.C.	35.64	32.80	54.39	32.89	40.38	52.53	62.47	63.63	65.89	74.42	87.18	78.72
@ TAN	40.67	66.94	47.60	51.34	62.20	70.28	25.99	103.25	106.08	90.66	48.66	76.91
* Polyphenols	1.78	1.84	2.13	1.90	1.84	1.66	1.30	1.78	1.30	1.48	1.30	1.30

@ Values expressed as ml of 0.1 N NaOH required to neutralize the acids present in plant extract of 100 g fresh tissue.

* Values expressed as g 100 g^{-1} fresh tissue.

the R.W.C. is increased considerably over control with increasing NaCl concentration while Local variety shows increased R.W.C. particularly at higher NaCl concentrations.

ii) Effect of NaCl treatment on TAN :

The results of the effect of NaCl on TAN are depicted in Table 8. The NaCl concentration also affect TAN. In the Local variety, NaCl treatment enhanced TAN over control and attained a maximum level at 0.4% NaCl concentration. While JLSF-88 variety show remarkable increase in TAN over the control at all the concentration of NaCl.

Torii and Laties (1966) have shown that delivery of ions into the vacuole effectively removed organic acids form the cytoplams by sequestering the salt of the acid in the value. The increase in TAN due to salinity was previously reported in maize by Strogonov (1964). Karmarkar (1965) has shown that NaCl treated Bryophyllum pinnatum increases TAN upto 0.04 M NaCl concentration, however further increase in NaCl concentration decreases TAN values (Zyl et al., 1974). Bernstein (1975) reported that organic acids can play a role in osmotic adjustment i.e. mechanism of adaptation. Hiatt (1967) has suggested that synthesis of acids is because of unbalanced uptake of ions and not because of their concentrations. Willert (1975), Willert and Troughton (1978) have recorded that PEP-case activity controlled by inorganic phosphate and NaCl resulted in increase in TAN. The similar results were observed in many succulent halophytes (Venkatesalu and Cheppappan, 1988).

In the present investigation the similar results are obtained. In the Local variety TAN increases with progressive increase in NaCl concentration over control and attained maximum value of 70.28 at the 0.4 % NaCl treatment however JLSF-88 show different behaviour with NaCl treatment. At the low NaCl concentration of 0.025% and 0.05% the TAN values are maximum, 103.25 and 106.08 respectively. But further increased NaCl concentration reduce TAN still the values are higher than the control. Karmarkar and Joshi (1969) have observed the similar results in Bryophyllum pinnatum where 0.04 M NaCl concentration gives the highest TAN and further increase in NaCl concentration decrease TAN.

Such fluctuations of TAN are because of Ca uptake during NaCl treatment. Ranganekar (1975) and Bartakke (1977) have recorded the highest TAN values when maximum accumulation of calcium in the leaves of tomato and Aloe barbadensis respectively under NaCl treatment. Our results of the present investigation are similar and the Local variety shows the highest TAN of 70.48 at 0.4% NaCl with the highest calcium content of 6.7 % dry wt. (Table 9). The JLSF-88 also shows the highest TAN value of 106.08 at 0.05 % NaCl treatment when the highest calcium of 3.65 % dry wt. (Table 9).

iii) Effect of NaCl treatment on Polyphenols content:

Table 8 records the effect of NaCl on the polyphenolic content in two safflower varieties. Both varieties show enhanced polyphenol content. The Local variety show maximum polyphenols at 0.05% NaCl treatment and gradually decline with further increase in NaCl treatment. However JLSF-88 show maximum polyphenols at 0.025 % NaCl treatment and content decreases with further increase in NaCl concentration, but not below the control value.

The increase in polyphenol content due to salinity was recorded by many workers. Karadge and Chavan (1981) and Chavan (1980) reported that, due to the salinity polyphenols were increased in groundnut cv TMV-10 and ragi respectively. Shetty (1971) and Jamale (1975) have recorded similar results in mangroves. However there are few reports which show the decrease in polyphenol content due to salt effect. Karadge (1981) in Portulaca oleracea and Krishnamoorthy and Siddique (1985) in cow pea reported the decrease in polyphenol content as these plants are salt sensitive. In the present investigation both the safflower varieties show polyphenol content decreased at higher NaCl concentration. Hence they are possibly salt sensitive at higher NaCl concentration.

However the particular concentration of NaCl stimulates the polyphenol content (Shetty, 1971 and Jamale, 1975). From the Table 8 it is clear that at 0.05 % NaCl concentration polyphenols increased in Local variety while such increase in JLSF-88 is at 0.025 % NaCl concentration. These results are similar to that of Chavan (1980) and Dixit *et al.*, (1986) in *Crotolaria retusa*.

iv) Effect of NaCl treatment on Photosynthetic pigments:

The results of effect of NaCl treatment on chlorophylls are recorded in Table 9. The chlorophyll synthesis is much more in JLSF-88 than Local variety due to the NaCl treatment. The chlorophyll synthesis is stimulated at 0.05% NaCl concentration in Local variety while in JLSF-88 stimulation is at 0.1 % NaCl treatment. The total chlorophylls in Local variety decreased while in JLSF-88 enhanced over control.

Many workers have shown inhibitory as well as stimulatory effects on chlorophylls due to the NaCl treatments. Strogonov *et al.*, (1974) have recorded that accumulation of chlorophylls depends upon the specific nature of plant. According to Chimiklis and Karlander (1973) the NaCl treatment reduced total chlorophylls per cell and chlorophyll 'a':'b' ratio in *Chlorella.* However Hegde (1972) in rice, Nimbalkar (1973) in sugar cane, Jamale (1975) in mangroves, Chavan (1980) in ragi, Toro (1987) in *Setaria italica* have

Table 9 : Effect of NaCl treatment on the photosynthetic pigments in the leaves of two safflower (<u>Carthamus</u> <u>tinctorius</u> L.) varieties.

Parameters	LOCAL variety						Var. JLSF-88					
	Control	NaCl treatment					Control	NaCl treatment				
		0.025%	0.05%	0.1%	0.2%	0.4%		0.025%	0.05%	0.1%	0.2%	0.4%
* Chlorophyll 'a'	98.16	76.31	106.34	102.68	101.53	115.02	94.50	115.865	93.17	127.22	122.46	118.57
*Chlorophyll 'b'	95.28	48.56	103.255	82.66	66.665	75.925	74.72	99.71	86.17	106.48	97.37	76.81
* Total Chlorophylls	193.38	124.835	209.51	169.245	168.13	159.07	169.17	210.51	179.27	233.63	219.52	195.31
Chl. 'a' / Chl. 'b'	1.03	1.57	1.03	1.24	1.52	1.52	1.27	1.16	1.08	1.19	1.26	1.54
*Carotenoids	7.8	5.6	8.8	8.8	7.4	7.2	8.2	9.2	6.4	8.8	8.4	5.8

* Values expressed in mg 100 g^{-1} fresh tissue.

shown the stimulation on chlorophyll synthesis at lower NaCl concentration. The similar results in safflower were reported by Ahmed et al.,(1977). Sivtsev (1973) has recorded that chlorophyll 'a' and 'b' decline under low salinity treatment but enhanced over control with higher salinity treatment. Similar results were previously recorded by Ahmed et al.,(1979) in castor, bean, flax and sunflower and Krishnamurthy et al.,(1987) in rice. In the present investigation, Local variety show same pattern however JLSF-88 show increase in chlorophyll 'a' and 'b' over control under NaCl treatment.

The carotenoid content are recorded in Table 9. The NaCl treatment shows stimulatory increase in carotenoid at different salinity levels. The increase in carotenoid is due to its oxidized form - viloxanthin (Strogonov, 1974). Udovenko et al.,(1974) have recorded that due to salinization (3.5 to 7.0 at NaCl) in barley and wheat, carotenoids diminished first and then reach to control level while at higher NaCl concentration they suppressed. The increasing carotenoid content due to NaCl treatment is recorded in the present investigation.

c) Effect of NaCl treatment on the inorganic constituents:

Salinity affects various aspects of plant metabolism which may reduce yield due to the ionic imbalance. Many essential and non-essential elements are adversely affecting plant metabolism due to salinity stress. In the present investigation the accumulation of different elements in the leaves of two safflower varieties, Local and JLSF-88 are studied and the results are depicted in Table 10.

i) Sodium :

Sodium is an important micronutrient which control plant growth and development. The values of sodium in the leaves of two safflower varieties are (Table 10) ranging from 1.1 to 1.7 % dry wt. In both the varieties sodium content increases with progressive increase in NaCl treatment. Increase in sodium content due to salinity was reported by several workers (Downtown, 1977 and Karadge and Chavan, 1980). Heikal (1976) has reported the accumulation of sodium which shows many harmful effects such as reduction in leaf number, leaf length and leaf area.

Werkhoven et al.,(1966) have reported that due to accumulation of sodium the safflower yield and growth is reduced. Pozuelo and Felipe (1972) have shown that accumulation of sodium is restricted to root so that leaves are kept away from the toxic effect of sodium. Devi et al.,(1980) have significantly recorded that sodium could have increased the metabolic activity in safflower. They have also observed a positive correlation between growth rate and $^{14}CO_2$

Table 10 : Effect of NaCl treatment on inorganic constituents in the leaves of two safflower (Carthamus tinctorius, L.) varieties.

Inorganic element	Local variety						Var. JLSF-88					
	Control	NaCl concentration					Control	NaCl concentration				
		0.025%	0.05%	0.1%	0.2%	0.4%		0.025%	0.05%	0.1%	0.2%	0.4%
Na^{+}	1.1	1.08	1.35	1.375	1.40	1.40	1.425	1.10	1.225	1.5	1.625	1.7
K^{+}	1.7	1.05	1.05	1.0	0.90	0.85	2.2	1.6	1.5	1.55	1.55	1.55
K/Na	1.55	0.98	0.78	0.73	0.69	0.66	1.54	1.27	1.27	1.03	0.92	0.88
Ca^{2+}	5.1	5.65	4.00	4.50	5.75	3.55	2.60	2.75	3.65	3.05	2.20	3.25
Mg^{2+}	1.40	1.12	0.74	0.94	1.06	0.73	0.70	0.54	0.69	0.61	0.30	0.66
Fe^{3+}	0.56	0.53	0.47	0.49	0.32	0.57	0.48	0.49	0.83	0.44	0.32	0.36
Cu^{2+}	0.13	0.13	0.14	0.13	0.15	0.13	0.12	0.09	0.12	0.14	0.13	0.12
Zn^{2+}	0.24	0.18	0.14	0.12	0.18	0.21	0.16	0.37	0.10	0.14	0.12	0.21
Mn^{2+}	0.02	0.02	0.02	0.02	0.02	0.02	0.021	0.02	0.03	0.02	0.01	0.2
Cl^{-}	1.64	4.32	4.44	5.15	5.68	6.09	1.86	1.91	2.49	2.54	5.68	6.73

Values expressed in g 100 g^{-1} dry tissue.

incorporation under salinity treatment. Ahmed *et al.*, (1977) have shown that NaCl treatment in safflower increased pigment content and photosynthetic activity. Aslam (1975) has given a interaction between sodium and potassium in growth and recorded that added sodium reduced potassium content of all the plant parts. Kurian and Iyengar (1972) have reported that safflower seedlings irrigated with sea water reduced sodium uptake and increased nitrogen, potassium and calcium. Recently Janardhan *et al.*, (1986) have shown that safflower varieties accumulate considerable quantities of sodium with successive increase in salinity levels.

Our results also show similar pattern at higher NaCl concentration in both varieties however, at lower NaCl concentration of 0.025 % and 0.05 %, the sodium content decreases over control in both the safflower varieties. While potassium:Sodium ratio decreases with progressive increase in NaCl concentrations in both varieties indicating the salt sensitive nature however the ratio delcined more significantly in Local variety than JLSF-88.

ii) Potassium :

The results of the effect of NaCl treatment on potassium content in the leaves of two safflower varieties are depicted in Table 10. From these it is clear that NaCl treatment adversely affected the potassium content in the leaves of both varieties. The ratio of potassium:sodium is also declined with increase in NaCl concentrations in both varieties.

Potassium is a monovalent cation required by the plant for many metabolic processes such as osmotic regulation (Okanenko et al., 1978), growth initiation and regulation (Kramer et al., 1980). But a major role of potassium is to activate enzymes. Evans and Sorger (1966) have recorded 46 enzymes activated by potassium. The average value of potassium in plant is 1% dry wt.(Epstein, 1972). From our results it seems that both safflower varieties are rich in potassium content.

The NaCl treatment shows a high correlation with potassium. Many workers have shown a significant decrease in potassium content when plants are subjected to the salt stress (Cooper and Dumbroff, 1973; Karadge et al., 1983 and Patil, 1984). However, safflower irrigated with sea water show increased potassium content (Kurian and Iyengar, 1972). Aslam (1975) has reported that increase in potassium, decreased calcium and magnesium content irrespective of added sodium. Recently Bisht et al., (1987) have shown the effect of potassium deficiency on growth and development and exhibited necrotic spots on the middle of the safflower leaves. In the present investigation the reduction in potassium content due to the NaCl treatment adversely affected the growth

(Table 7). Janardhan et al., (1986) have reported that salinity reduced potassium content in safflower. In the present investigation similar results obtained in both varieties.

iii) Potassium/sodium ratio :

The potassium : sodium ratio (Table 10) declined in both safflower varieties with increase in NaCl concentration. However potassium : sodium values found in JLSF-88 are higher than Local variety because of efficient absorption of potassium by JLSF-88 variety. Janardhan et al., (1979) have demonstrated that salt tolerance of crop varieties is characterised by maintenance of higher potassium : sodium ratio. Our results are similar to the reports of Janardhan et al., ( ) in safflower varieties. The ratio mainly depends on exclusion of sodium with uptake of potassium. The higher level of NaCl interfer the absorption of potassium which probably lower the ratio.

iv) Calcium :

The results of effect of NaCl treatment on calcium content are recorded in Table 10. It is clear that Local variety is richer in calcium than JLSF-88. The increasing NaCl concentration increases the calcium content in both safflower varieties. The calcium content increased in Local variety at 0.2 % NaCl treatment however, JLSF-88 show reduced calcium content at the same concentration over control.

Calcium is generally regarded as the most immobile element (Ferguson and Bollard, 1976). Marinos (1962) has suggested that calcium involves with membrane system. Rains *et al.*, (1964) have reported that calcium is essential for ion transport mechanism. Calcium also stimulates the activity of enzyme ATP-ase, adenylkinase, succinic dehydrogenase and argininekinase (McElory and Nason, 1954). However Chimklis and Karlander (1973) have shown that salt stress damage is recovered by the application of calcium sulphate. Bernstein and Hayward (1958) have observed that sodium and calcium balance must be present to avoid the toxic effects of sodium alone. The probable explanation was given earlier by Kearney and Cameron (1902) according to them calcium neutralizes the harmful effects of sodium.

In the present investigation the calcium content increases over control in both safflower varieties. The increased calcium content in JLSF-88 over control is an adaptive feature while in Local variety it is lacking. However a significant increase was observed at 0.2% NaCl concentration. This suggest that calcium plays an important role in salt tolerance mechanism in JLSF-88 as compared to Local variety.

v) Magnesium :

The magnesium content in the leaves of two safflower varieties are depicted into the Table 10. Both varieties show different response to NaCl treatment. In the Local variety, magnesium content reduced considerably with 0.05% and 0. 4 % NaCl concentrations. while in JLSF-88 magnesium content is highly reduced at 0.1% NaCl treatment. Magnesium is a constituent of chlorophyll molecule and hence it plays an important role in the synthesis of chlorophyll and in many enzymatic reactions. However the salinity affects magnesium content. According to Waisel (1977) and Laszlo and Kuiper (1979) the magnesium content reduced due to the salinity. Our results are similar to these findings. But the losses of magnesium in JLSF-88 are less as compared to the Local variety over the control. This is probably because of calcium which inhibit magnesium absorption. Moore et al., (1961) have reported that magnesium absorption is checked by calcium. Atkinson et al., (1967) have reported that magnesium maintain the salt balance in the leaves of Aegialitis. From our results it can be concluded that magnesium retention under NaCl treatment is superior in JLSF-88.

vi) Iron :

Iron is an immobile micronutrient. The results of effect of NaCl treatment on iron content are recorded in Table 10. Both varieties show decreased iron content due to NaCl treatment, however the stimulatory effect in JLSF-88 is observed at 0.05% NaCl concentration.

Dahiya and Singh (1976) have shown that due to salinity iron content increases. Iron is a vital micro-element involved in many metabolic processes (Nason and McElory, 1963). Iron is essential in photosynthesis as being a constituent of non-heme iron protein, ferrodixin as well as in nitrogen fixation (Epstein, 1972 and Ralph, 1975). The growth is enhanced with increase in iron content (Ivan and Drev, 1979).

Epstein (1972) has recorded an average of 0.011 % dry wt. of iron in many plants. The values of iron in other oil seed crops are lesser than in safflower. Karadge and Chavan (1981) have recorded a range of 0.06 to 0.11% dry wt. in groundnut varieties. Kannan (1969) has reported that higher concentration of calcium inhibits iron absorption in leaf cells of tomato. The reduced iron content in Local variety at 0.02 % NaCl treatment is probably because of high calcium at the same NaCl concentration. However in JLSF-88 both calcium and iron reduced at 0.2 % NaCl treatment over control. Bartakke (1977) has shown that iron content increases upto 0.1 M NaCl and decreases with progressive NaCl treatment in Aloe barbadensis. The increase in iron content due to salinity was also reported in groundnut and Sesbania by Patil (1984).

vii) Copper :

The effect of NaCl on copper content in both the varieties show slight change (Table 10). In the Local variety slight increase in copper content is observed at 0.05% and 0.2% NaCl concentration, however in JLSF-88 the copper content reduced with increase or decrease after 0.1% NaCl treatment.

Copper is component of several metallo-enzymes including ascorbic acid oxidase, tyrosinase and cytochrome oxidase (Sutcliff and Baker, 1981). But lower plants like *Chlorella* affected severely due to application of copper. The high accumulation of copper adversely affected growth pattern (Den Dooren de Jong, 1965). However in the higher plants copper inhibition is an elastic, reversible strain. The data of effect of salinity on copper content are scanty. Our results show a slight increase in copper content in both varieties under NaCl treatment.

viii) Zinc :

Zinc is a micro element required in plants. It is associated with number of enzymes including dehydrogenases and peptidases but recently it was discovered that zinc specifically activate carbonic anhydrase. Its deficiency was associated with disturbance in auxin metabolism (IAA).

(Sutcliffe and Baker, 1981).

The results of effect of NaCl treatment on safflower varieties in zinc content are recorded in Table 10. Both varieties show different response for zinc. The zinc content reduced over control in Local variety due to NaCl treatment on contrary in JLSF-88 zinc increased at 0.025% NaCl treatment.

ix) Manganese :

Manganese is also a micro element. The accumulation of manganese due to NaCl treatment in the leaves of two safflower varieties are depicted in Table 10. A slight stimulatory effect at 0.05% NaCl treatment in JLSF-88 is recorded.

Cheniae (1970) has reported the role of manganese in Hill reaction. Manganese deficiency decreases the photosynthetic rate, leaf area, chlorophyll content etc. Stout (1961) has recorded the level of manganese critical for the growth is 0.005 % dry wt. Karadge *et al.* (1983) have shown that increasing salinity enhanced manganese content in the *Lippia nodiflora*. However, in the present investigation the manganese content is unchanged in Local variety while slight increase in at 0.05% NaCl treatment followed by decrease in manganese at high NaCl in JLSF-88.

x) Chlorides :

The most important anion of saline habitat is chloride. The values of chlorides in the leaves of two safflower varieties are recorded in Table 10. The values are ranging from 1.64% to 6.73 % dry wt. In both safflower varieties the chlorides show accumulation with increased NaCl concentrations.

Although chlorides act as an electron transporting agent in photophosphorylation, its accumulation affect various aspects of plants. The normal values of chloride in land plants vary from 1 to 3 % dry wt.(Ferry and Ward, 1959). According to Strogonov (1962) chloride salinity increase succulence in plants. In the present investigation we have also recorded the succulence which is possibly due to chlorides accumulated as a result of salinity treatment (Table 7). Black (1956) has reported the more accumulation of chlorides than sodium in the leaves which might be mainly due to passive flow of chlorides. The transpiration increases passive uptake of chlorides (Greenway, 1965).

The accumulation of chlorides in leaves due to NaCl treatment was previously reported by Hedge (1972) in rich var. Kala Rata, Nimbalkar (1973) in sugarcane Co-740, Jamale (1975) in *Avicennia alba.* Chloride accumulation is most prominent in the non-excreting group. The present investigation show accumulation of high chlorides in the leaves of both safflower varieties. This leads to succulent nature of leaves in safflower. Kole and Gupta (1982) have reported the depressed growth in safflower due to salinity mainly because of accumulation of chlorides (Tagawa and Ishizaka, 1963 and Ramana and Rama Das, 1978). Our results show similar correlation between chloride accumulation and decreased plant height in both the varieties of safflower.

d) Effect of NaCl treatment on enzyme activity :

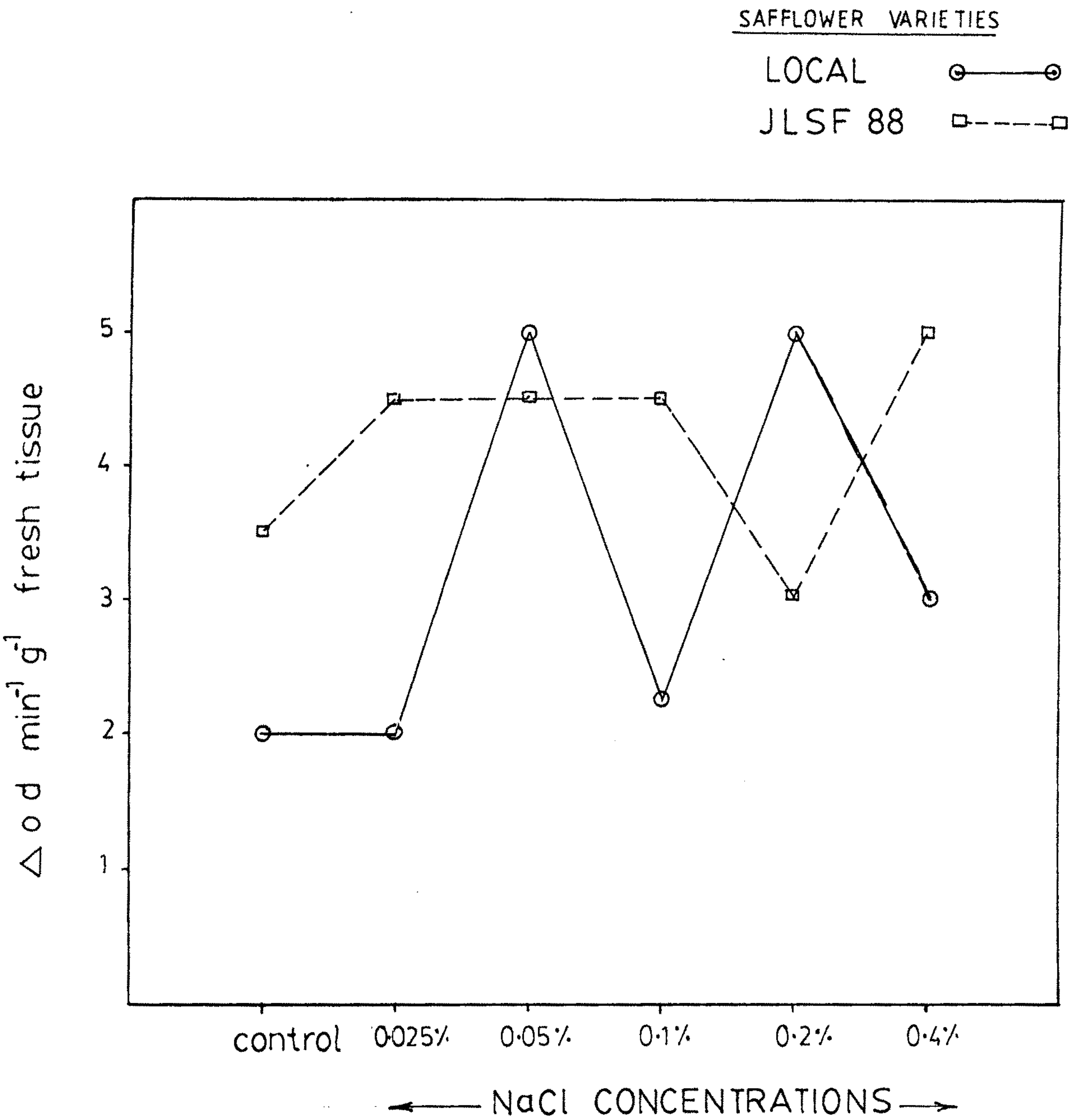
Udovenko and Alekseeva (1973) have reported that salt accumulation in salinized seedlings causes retardation of growth. This may be mediated through the effect of salts on the activities of several important enzymes. In the present investigation an attempt has been made to study the following enzymes as the effect of NaCl treatment.

1) Effect of NaCl treatment on the activity of enzyme-Peroxidase (EC 1.11.1.7)

The results of activity of enzyme peroxidase in the leaves of two safflower varieties under the effect of NaCl treatment are shown in Figure 8. The activity of enzyme peroxidase increases with increasing NaCl treatment in both safflower varieties, except a slight decrease at 0.2% NaCl treatment in JLSF-88. The stimulatory effect in both varieties are different. In the Local variety peroxidase activity increases sharply at 0.05 % and 0.2% NaCl treatment however in JLSF-88 the activity of peroxidase is high at 0.4 % NaCl treatment. In the JLSF-88 the activity of peroxidase remains constant at the initial stages but increased sharply at higher NaCl concentrations.

Peroxidase is widely distributed as oxidative enzyme located in various cell organellae (Fric,1976). Peroxidases are poryphyrin enzymes catalizing the oxidation of various substrates by hydrogen peroxide. Very few reports are available on salinity stress. Strogonov (1964) has reported a great increase in peroxidase activity in NaCl injured leaves of several plants. This may have played a role in the oxidation of accumulated substances leading to melanin formation from tyrosine in the necrotic areas. Poljakoff-Mayber et al., (1981) has given a significant function of enzyme peroxidase. The enhanced activity of peroxidase in an adaptive role in protecting leaf cells against oxygen toxicity caused by free radicles. Increasing activity of peroxidase due to salinity was reported by many workers including Rakova et al., (1969) in pea roots, Molokov et al., (1973) in rice, Patil (1984) in groundnut and Sesbania, Kalir et al., (1984) in Halimione portulacoides, Patel and Vora (1985) in maize. However decrease in peroxidase activity due to salinity was also recorded by Maliwal and Paliwal (1972). Flowers (1972) has recorded significant reduction in peroxidase activity in a salt tolerant plant Suaeda maritima. Our results of the

FIG. 8 : EFFECT OF NaCl TREATMENT ON THE ACTIVITY OF ENZYME PEROXIDASE IN THE LEAVES OF TWO SAFFLOWER (C~~O~~RTHAMUS TINCTORIUS, L) VARIETIES. A/



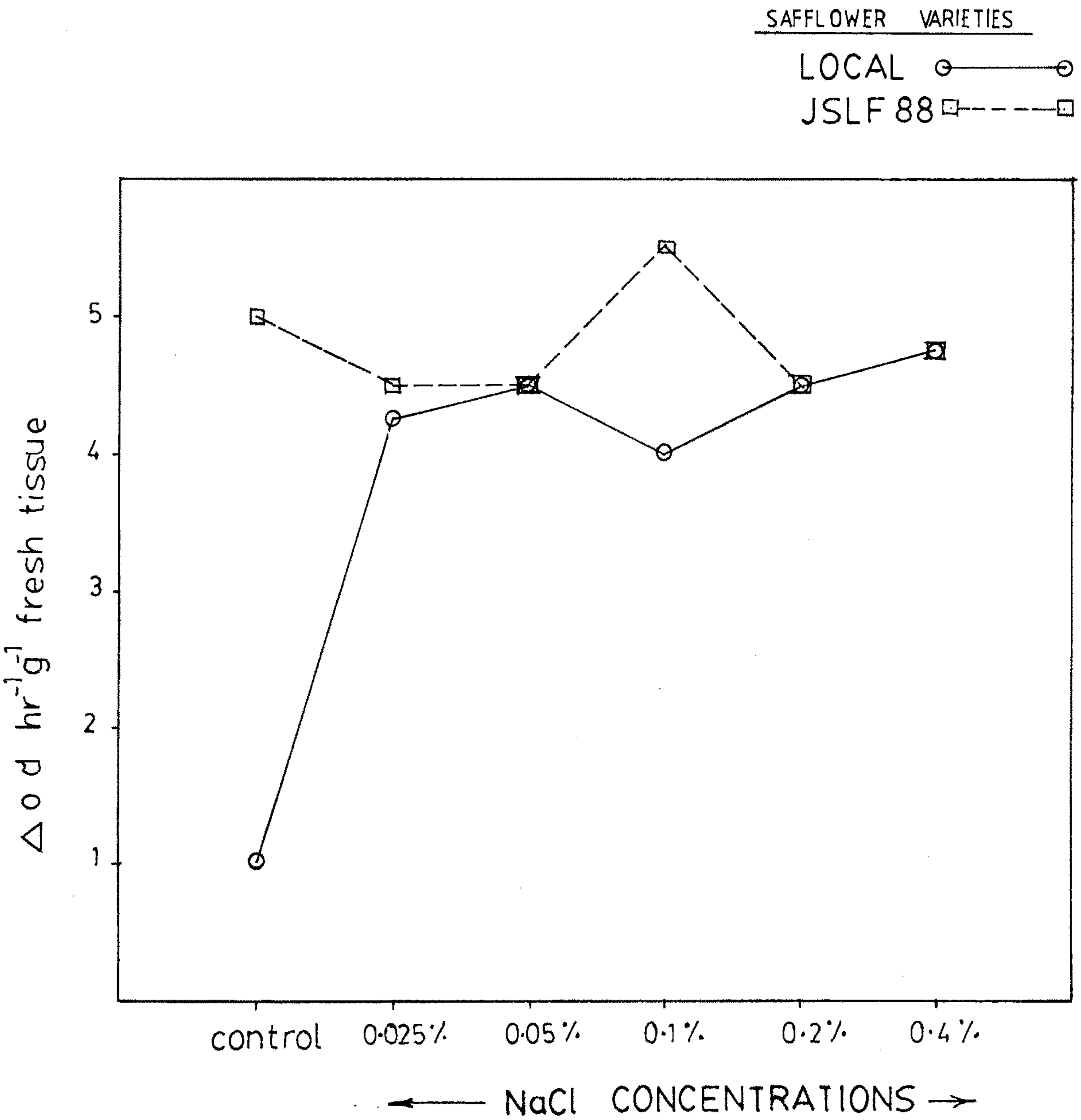
present investigation show enhanced activity of peroxidase in both safflower varieties under salt stress and show an adaptive feature against the NaCl toxicity effect.

2) Effect of NaCl treatment on the activity of enzyme Acid phosphatase : (EC 3.1.3.2)

The activity of Acid phosphatase in terms of change in optical density (OD) per hour per gram of fresh tissue under the effect of NaCl treatment in the leaves of two safflower varieties is shown in figure 9. The activity of acid phosphatase in both safflower varieties show different pattern. The enhanced activity of acid phosphatase due to NaCl treatment is found in Local variety, however the activity is more or less constant in JLSF-88 except at 0.1 % NaCl treatment where activity is increased over control and hence 0.1 % NaCl concentration may be a stimulatory dose for this enzyme.

The enzyme acid phosphatase involved in non specific breakdown of a variety of phosphate compounds including ATP (DeLeo and Sacher, 1970), or in the mobilization of nutrient reserves (Flinn and Smith, 1967). The effect of salinity levels or NaCl treatment was studied by many workers. Zhukovskaya (1971) has postulated that salinity induces new phosphatase which apparently increases the activity of enzyme acid phosphatase. Flowers (1972) has studied the

FIG. 9: EFFECT OF NaCl TREATMENT ON THE ACTIVITY OF ENZYME ACID PHOSPHATASE IN THE LEAVES OF TWO SAFFLOWER (CORTHAMUS TINCTORIUS, L) VARIETIES.



effect of NaCl salinity and found a slight stimulatory effect on acid phosphatase in Pisum while in Suaeda the activity is inhibited due to salinity. No significant effect of NaCl treatment on acid phosphatase was recorded (Weimberg, 1970). However Ahmad and Huq (1974) in halophytic spinach, Chavan (1980) in ragi, Karadge (1981) in Portulaca oleracea, Karadge and Chavan (1983) in Sesbania have shown enhanced activity of acid phosphatase due to salinity. Our results in Local variety also show enhanced activity of acid phosphatase as a result of NaCl treatment. Recently Patil (1984) has shown the decrease in acid phosphatase activity in groundnut subjected to salinity. Such decrease in acid phosphatase activity in JLSF-88 is also recorded in the present investigation. Murumkar (1986) has shown the increase in acid phosphatase activity restricted to higher salinity level (100 and 150 mM NaCl) however it is not altered at low salinity level. Our findings are similar to this view in JLSF-88 where at low salinity level the activity of acid phosphatase is not altered and increased at 0.1 % NaCl.