HEAVY METAL CONTENT OF VEGETABLES, CEREAL GRAINS, PULSES, TOBACCO AND GRASS, ALONG THE EFFLUENT CHANNEL.

CHAPTER - III

HEAVY METAL CONTENT OF VEGETABLES, CEREAL GRAINS, PULSES, TOBACCO AND GRASS, ALONG THE EFFLUENT CHANNEL

There is growing awareness of the hazards of environmental pollution in developing countries. Pollutants cause many physical, physiological and even genetic disturbances in man. Air, water and food are all potential sources of pollutants and, they can gain entry into the human body by the normal processes of breathing, drinking or eating. Today agriculture consumes high inputs like pesticides and fertilizers for raising food production. But their excessive use has been creating a variety of pollution problems, affecting development of flora and fauna, leading to accumulation of harmful chemical substances in the food and causing deleterious effects when consumed. Some of them are cancer causing or carcinogens, and thereby pose a great risk to the health of people. Accumulation of inorganics in water, soil, and flora from the inputs of chemical fertilizers is well established. Most notable in this respect is the accumulation of nitrate, which beyond a particular concentration (90 ppm), can cause diarrhoea and cynosis in infants. The nitrates can be converted in the digestive tract into nitrites and nitrosoamines and other nitroso compounds which are suspected agents of cancer in man. Nitrates can accumulate in food, as for eg, spinach, contain as much as 3600 ppm and lettuce and radish contain about 200 mg/100gms. Fluoride is another pollutant in water and food which can cause a serious affliction called fluorosis, an incurable bone disease. The incidence of this disease is high in areas having alkaline soils, rocky strata and a dry climate. The accumulation of fluoride by the body is faster under excessive alkalinity, resulting in mottling of teeth enamel, stiffness and pain in joints and, bone and spinal deformities. Cereal crops like jowar, maize and pearl millet grown on alkaline soil absorb higher amounts of fluoride and thereby contribute to the spread of the disease. Similarly, selenium is an element that can accumulate in plants growing on selenium rich soil. Such plants are toxic to animals grazing on them. Symptoms of toxicity are stunted growth, loss of appetite, shedding of hair and nails and gastro - intestinal disturbances. Other metals like lead, aluminium, cadmium, nickel, chromium, antimony, arsenic, mercury, copper and zinc are also known to cause various types and degrees of illness and diseases. Lead contamination of food leads to chronic illness characterized by severe anemia, and changes in the arteries of kidney. Like lead, the other metals are also known to cause many serious disturbances and ill effects when consumed through food and accumulated in the body.

It was reported previously (Chapter- I), that the effluent water coursing through the effluent channel is rich in metals and, that the content of various metals shows progressive increase from year to year. Due to the paucity of adequate water resources for irrigation, the villagers living along the effluent channel have taken recourse to the use of the channel water for irrigational purposes. During most parts of the year, water is pumped from the channel into the adjoining fields by use of water pumps and, variety of crops, vegetables and tobacco are cultivated. The continuous unchecked and unhindered pilferage of the channel water over the years has resulted in relatively higher levels of various metals in the soil along the channel (Chapter- II).

In the wake of our knowledge that most of the plants can accumulate metals in varying degrees and, since the grains, vegetables and tobacco plants grown along the channel find their way into the markets of Baroda city, there exists a potential threat and risk to human health. It is also likely that cattles and domestic animals which graze on the grass growing along the channel can also be affected. In this context, there is a need to monitor the levels of metals in these plants so as to make a rational assessment of the impact of the usage of the channel effluent for irrigation. Though the channel has been existing for the last 12 years there has never been an objective assessment of this aspect by any agency (Private or public) or individual what-so-ever. This has prompted the present study on the analysis of the metal content in the cereals, vegetables, tobacco leaves and grass along the effluent channel which are irrigated by the effluent water.

MATERIALS & METHODS

The major cereals cultivated by the villagers along the channel are maize, *(Zea maize* ; Fig- 1), Bajara *(Penisetum typhoidum* ; Fig- 2) and wheat *(Triticum aestivum)*. The grains of these plants have been collected during the years 1992 and 1993 and analysed for metal content. A commonly grown pulse, the red gram dhal (*Cajanus cajan*) was also collected and analysed. Some of the seasonal vegetables grown by the populace by irrigating with the channel water are the green chilli *(Capsicum annuum* ; Fig- 3), the cauliflower *(Brassica oleracea)*, the tomato *(Lycopersicon esculentam)*, the cabbage *(Brassica oleracea var-capitata* ; Fig- 4), the green peas *(Pisum sativum)*, the brinjal *(Solanum melongena* ; Fig- 5), the potato *(Solanum tuberosum)*, the bitter gourd *(Momordica charantia* ; Fig- 6) and geeloda *(Coccinia indica* ; Fig- 7).

A perennial vegetable found all along the channel is the drumstick *(Moringa oleifera* ; Fig- 8). All these have

Figure 1: View of the maize corn grown along the effluent channel.

Figure 2: A Crop of bajara along the channel


1


2

Figure 3: Chillies grown along the channel.

Figure 4: Cabbages cultivated along the channel

Figure 5: Brinjal cultivated along the channel

Figure 6: Bitter gourd grown along the channel

Figure 7: Drumstick tree by the side of the channel.


5


6


7

Figure 8: Geeloda grown along the channel

Figure 9: A tobacco plant along the channel

been analysed for their metal content. In addition, the metal content in the leaves of the tobacco plant *(Nicotiana tabaccum* ; Fig- 9) and the common grass, *(Cynodon dactylon)*, sources of entry into humans and cattles respectively, has also been assessed. The content of metals in the above, grown along the channel, has been analysed and compared with the content in the same grown in areas not using channel water for irrigation.

Sufficient amount of the various grains,vegetables, tobacco leaves, and grass were washed and oven dried. One gram material from each of them was taken and mixed with 94 ml distilled water containing 3ml each of concentrated sulphuric acid and nitric acid, in a conical flask. The flasks were then kept for digestion on a hot plate till the volume shrank to 5 ml. The volume was adjusted to 100 ml with distilled water and was then filtered with Whatman no. 40 filter paper. Ten ml of the filtrate was taken and diluted to 100 ml with distilled water and aspirated in an atomic absorption spectrophotometer for analysis of metal content. Details of analysis of individual metalS are as given in chapter- I. The values are expressed as mg/kg (ppm).

RESULTS

GRAINS

Of the various metals analysed, Cu,Cr,Zn,Ni,Pb Cd, and Fe,except for Zn, which is found in high concentrations (108.7 mg/kg), all others were found in trace amounts ranging between 1 to 2 mg/kg in Control maize. The Fe content was slightly higher (8.2 mg/kg). The maize grown along the channel had much higher content of all the metals with Ni being the maximum (63.3 mg/kg) and Pb the least (3.3 mg/kg). Control wheat showed very high content of Zn and Cu (99.3 mg/kg and 76.2 mg/kg respectively). The Fe content was 6.7 mg/kg while all other metals were in 1 to 2 mg/kg range. All the metals were significantly higher in the wheat grown along the channel with the greatest increase being with respect to Cd (21.3 mg/kg) and Fe (41.3 mg/kg), Cu showed the least increase (89.8 mg/kg). With respect to control bajara, the metals found in higher concentration were Zn (262.8 mg/kg) and Cu (136.2 mg/kg), all others were in the 1 to 2 mg/kg range. The metal content in the bajara grown along the channel was significantly higher, with the greatest increment being for Cr (63.2 mg/kg), followed by Fe (25.7 mg/kg) and the least increment was that of Cu (204 mg/kg) and Zn (427.4 mg/kg). Higher metal contents were recorded in the red gram dhal grown along the channel as compared to the control dhal. Whereas the levels varied from a minimum of 1.12 mg/kg for Cu and 1.15 mg/kg for Pb to a maximum of 9.9 mg/kg for Zn in control dhal, the levels in the channel dhal varied from a minimum of 2.5 mg/kg for Cu to a maximum of 61.5 mg/kg for Ni. The data on the metal content in grains is represented in table 1.

VEGETABLES

The data on the metal content in vegetables is shown in table 2. The control vegetables showed varying levels of the metals, the highest content being for Fe in brinjal (12 mg/kg) and Zn in cabbage (11.1 mg/kg). significant level of Fe in bitter gourd (10.3 mg/kg), the tomato (8.2 mg/kg) and the cauliflower (8.0 mg/kg), of Ni in brinjal (8.7mg/kg) and, of Zn in the cauliflower (7.8 mg/kg), the potato (7.5 mg/kg) and the green chilli (6.6 mg/kg) were recorded. All vegetables grown along the effluent channel showed significantly higher levels of all metals tested.

In terms of very high level of accumulation, Zn was the major metal accumulated by almost all the vegetables ranging from a minimum of 10.8 mg/kg in the tomato to a maximum level of 86.7 mg/kg in the drumstick. All the metals ranged between 15 mg/kg to 48 mg/kg (See table 2). The next higher concentration was that of Fe, ranging between 18.2 mg/kg in

TABLE 1: METAL CONTENT (mg/kg) AND PERCENTAGE CHANGE IN CEREAL GRAINS AND A PULSE FROM CHANNEL IRRIGATED AND NON CHANNEL IRRIGATED AREAS

SR. NO.	METAL		MAIZE	WHEAT	BAJARA	TUAR RED GRAM DHAL
1.	Cu.	C	1.9	76.3	136.2	1.1
		P	16.3	89.8	204.0	2.6
		I	757.8	17.7	49.8	127.7
2.	Cr	C	1.1	1.1	2.0	1.3
		P	3.9	3.4	63.2	8.2
		I	245.5	201.0	3060.0	556.8
3.	Zn	C	108.7	99.4	262.8	9.9
		P	318.1	367.4	427.4	38.2
		I	195.2	269.9	62.6	285.0
4.	Ni	C	2.1	1.0	1.1	1.3
		P	63.4	2.1	3.2	61.5
		I	2914.2	108.3	191.0	4820.0
5.	Pb	C	1.3	1.1	1.3	1.2
		P	3.3	2.4	2.9	4.2
		I	153.8	109.3	123.0	267.0
6.	Cd	C	2.1	2.4	2.2	5.7
		P	8.9	21.3	10.7	10.3
		I	323.8	787.5	386.0	80.7
7.	Fe	C	8.2	6.7	2.8	4.8
		P	21.7	41.3	25.7	28.6
		I	164.6	516.4	817.8	495.8
8.	Cl	C	3520.0	5111.0	3876.0	6212.0
		P	7110.0	6017.0	5232.0	6983.0
		I	101.0	17.7	35.0	12.4

C - CONTROL SAMPLE VALUE (NON-CHANNEL IRRIGATED)

P - POLLUTED SAMPLE VALUE (CHANNEL IRRIGATED)

I - PERCENT INCREASE IN METAL CONTENT

TABLE 2: METAL CONTENT (mg/kg) IN VEGETABLES, GRASS AND TOBACCO FROM CHANNEL IRRIGATED AND NON CHANNEL IRRIGATED AREAS

SR. NO.	METAL		CHILLI	DRUMSTICK	CAULI-FLOWER	BRINJAL	POTATO	TOMATO	CABBAGE	GREEN PEAS	BITTER GOURD	GEELODA (TONDLI)	TOBACCO	GRASS
1.	Cu.	C	1.3	2.3	2.4	5.2	2.0	1.4	1.7	1.9	2.0	3.0	2.3	1.2
		P	6.0	39.0	33.0	29.0	9.2	11.8	20.7	15.0	17.0		11.8	3.4
		I	351.1	1573.8	41.7	457.6	364.2	739.3	1147.0	702.1	750.0	333.3	13.5	198.0
2.	Cr	C	1.2	1.3	2.0	1.2	1.2	1.2	1.2	1.1	4.0	5.0	1.7	1.1
		P	11.3	3.1	3.3	2.0	1.6	7.6	8.3	7.1	21.0	17.0	9.9	2.1
		I	837.5	135.3	66.4	68.8	33.3	535.4	615.3	578.6	425.0	240.0	495.8	91.6
3.	Zn	C	6.6	1.3	7.8	3.6	7.5	2.2	11.2	6.4	5.0	4.0	8.0	1.8
		P	31.9	86.8	20.3	48.1	22.6	10.8	42.6	33.9	21.3	14.2	32.8	108.6
		I	382.9	6422.5	160.3	1236.8	201.6	390.9	281.9	431.4	326.0	272.5	309.4	6107.1
4.	Ni	C	1.0	1.2	1.4	8.7	1.3	1.2	1.5	1.1	3.0	4.0	1.2	1.5
		P	2.9	2.2	2.2	18.8	2.3	2.3	2.5	2.1	10.2	21.3	2.5	3.9
		I	190.0	81.3	54.3	115.5	82.0	89.2	63.3	97.9	240.0	432.5	111.0	156.9
5.	Pb	C	2.1	1.6	2.3	2.8	1.3	5.2	1.6	1.4	4.0	4.0	4.3	8.2
		P	6.8	9.2	6.8	26.3	9.8	91.3	66.3	8.6	21.1	3.1	44.5	46.8
		I	217.7	475.0	195.0	837.5	684.0	1665.8	4045.6	529.5	427.5	677.5	92.0	471.0
6.	Cd	C	5.4	1.9	2.2	2.2	1.2	1.4	1.9	1.9	3.0	2.0	2.5	1.6
		P	22.6	7.9	4.9	8.8	8.8	6.2	7.5	4.7	9.0	10.1	65.4	3.0
		I	321.6	314.2	122.0	298.9	629.2	344.3	305.4	148.0	200.0	405.0	2517.2	81.9
7.	Fe	C	3.0	4.0	8.0	12.0	3.2	8.2	6.0	14.0	10.3	4.0	2.4	2.9
		P	9.0	12.0	18.2	32.1	10.1	31.2	21.7	24.1	41.3	13.3	20.7	21.2
		I	200.0	200.0	127.5	167.5	215.6	280.5	261.7	72.1	301.0	232.5	762.5	631.0

C - CONTROL SAMPLE VALUE (NON-CHANNEL IRRIGATED)

P - POLLUTED SAMPLE VALUE (CHANNEL IRRIGATED)

I - PERCENT INCREASE IN METAL CONTENT

the cauliflower to 41.3 mg/kg in the bitter gourd. Except for the green chilli (9 mg/kg), the potato (10.1 mg/kg), the drum stick (12 mg/kg) and the geeloda (13.3 mg/kg), all other vegetables accumulated Fe in the range of 20 to 30 mg/kg. Two other metals which were accumulated at significantly higher levels, were copper and lead by as many as five vegetables. They are, the green peas (15 mg/kg), the bitter gourd (17 mg/kg), the cabbage (20.7 mg/kg), the drumstick (39 mg/kg) and the brinjal (29 mg/kg) for Cu, and the bitter gourd (21.1 mg/kg), the brinjal (26.2 mg/kg), the geeloda (31.1 mg/kg) the cabbage (66.3 mg/kg) and the tomato (91.3 mg/kg) for pb. Chromium, Ni, and Cd were concentrated to significantly higher levels only in the bitter gourd and the geeloda 21 mg/kg and 17 mg/kg, the brinjal and the geeloda 18.7 mg/kg and 21.3 mg/kg and, the green chilli (22.6 mg/kg) respectively. All the other vegetables have relatively lesser levels of accumulation of other metal. The detailed data in the metal contents in the vegetable is represented in table 2.

TOBACCO LEAVES AND GRASS

In general, the metal content of the control tobacco leaves varied between a minimum of 1.1 mg/kg for Ni to a maximum of 8 mg/kg for Zn. Except for Pb (4.3 mg/kg), all other metals were present in the range of 1 to 2 mg/kg. The tobacco leaves of the channel area had significantly higher metal content. The least elevation was with respect to Ni (2.4 mg/kg) and Cr (9.8 mg/kg); all other metals were accumulated in the range of 20 mg/kg (Fe) to 65.4 mg/kg (Cd). Except for Pb (8.1 mg/kg), all other metals were present in the range of 1 to 2 mg/kg in the grass growing in other areas. However, the grass in the experimental area showed significantly higher levels of all metals, with the least incre ment being for Cr (2 mg/kg), Cd (2.9 mg/kg), Cu(3.4 mg/kg) and Ni (3.8 mg/kg). Greater accumulation was found with respect to Fe (21.2 mg/kg), Pb (46.7 mg/kg) and, Zn (108.6 mg/kg). The data of the metal content in tobacco leaves and grass is given in table 2.

DISCUSSION

Plants can absorb and accumulate metals from the soil or the environment and, the levels of various metals in the vegetation in a given area can reflect the extent of metal pollution in the environment or, in the soil of the area. Water is the most limiting factor for plant growth and, the effluent channel from Dhanora (Industrialized Nandesari Belt), in Baroda to Nahar in Jambusar, before its confluence with the Mahi estuary, has become a boon for the villagers along the channel as they pump the water from the channel for growing various types of vegetables and cereals. In this connection, heavy contamination of the soil along the channel by metals has been shown (chapter. II). The present data shown in tables 1 and 2, reveal higher content of various metals in various vegetables and cereals grown in the villages along the channel as well as in the grass in this stretch of land. The relation between environmental pollution and the pollutant load of vegetation is recorded by many investigators. Sarangi *et al.* (1993) in their studies around Sargipali lead - zinc mines in Sundargarh, Orissa, have shown presence of some heavy metals in the leaves of some plants growing in the area as a reflection of the presence of metals in the mine water. They reported the presence of Cu in the range of 0.002 ppm in *Phoenix sylvestries* to 0.034 ppm in *Ficus benghalensis,* Zn in the range of 0.026 ppm in *Gardensia latifolia* to 0.094 ppm in *Anogeissus latifolia* and Pb in the range of 0.01 ppm in *Phoenix sylvestries* to 0.145 ppm in *Ficus benghalensis*. The accumulation of Zn, Cd, Pb and other heavy metals in plants growing over mineral deposits have been studied by many workers (Chapman and Shackletle, 1960; Warren and Delavault, 1960; Timperley *et al.*, 1970; Brooks, 1972; John *et al.*, 1972; Jones *et al.*, 1973; Cunningham *et al.*, 1975; Hasset *et al.*, 1976; Miller *et al.*, 1977; Barry and clark, 1978). In India, however, very little work is done on the biogeochmistry of heavy metals (Tiagi and Aery, 1981, 1982, Aery and Tiagi, 1987).

In a recent study in the Hooghly Malda esturine complex of West Bengal, (where sewage and effluents from Calcutta, Howrah and the newly developing Haldia complex are dumped), Mitra *et al.* (1994) have shown the accumulation of Zn, Cu, Mg, Fe, Co, Ni and Pb in the root, stem and leaf of the plants, *Ipomea pescarpes* from Nayachar island opposite to the Haldia Industrial belt. Their studies have shown the presence of various metals (in ppm) ranging from 152.8 to 246.3 in the root, 136.4 to 204.0 in the stem and 113.7 to 190.0 in the leaf of Zn, 49.3 to 99.7 in the root, 34.8 to 72.8 in stem and 19.7 to 29.2 in the leaf of Cu, 293.8 to 402.7 in the root, 258.9 to 372.1 in the stem and 230.3 to 314.8 in the leaf of Fe, and 1.9 to 12.9 in the root, 2.8 to 3.8 in the stem and 2.0 to 6.9 in the leaf of Ni.

The accumulation of various metals in such high concentration by various parts of *Ipomea pescarpes* by manifesting without any deleterious effects on growth has given reason for Mitra *et al.*(1994) to suggest the suitability of this plant to be used in biological treatment of industrial effluents prior to their discharge on land or in water. Similarly, Kumawat (1990) in his studies on heavy metals in industrial and non-industrial areas near Ujjain city has recorded higher metal content in the foliage of different plants like Cassia, Dalbergia, Eucalyptus, FIcus, Madhuca, Mangifera, and syzygium grown near industrial areas, ranging from 0.43 to 2.45 ppm of Cd, 0.32 to 1.21 ppm of Cr, 10.0 to 62.5 ppm of pb, 90.0 to 1445.6 ppm of Fe, 19.0 to 64.0 ppm of Mg, 7.0 to 50.0 ppm of Cu, 6.0 to 70 ppm of Ni, and 6.0 to 40.0 ppm of Cu.

In the present study on 10 different vegetables grown along the channel, the content of all the metals studied is found to be higher than in the same vegetables grown in other areas. On a comparative basis, the metal content in the non effluent channel irrigated vegetables as against the effluent channel irrigated vegetables range between (in ppm) 1.1 to 5.2 Vs 3.3 to 39.0 for Cu, 1.0 to 5.0 Vs 1.6 to 21.0 for Cr, 1.3 to 7.8 Vs 10.8 to 108.6 for Zn, 1.0 to 8.7 Vs 2.1 to 21.3 for Ni, 1.2 to 8.1 Vs 6.8 to 91.3 for Pb, 1.2 to 3.0 Vs 2.0 to 22.6 for Cd and 3.0 to 14.0 Vs 9.0 to 41.3 for Fe respectively. These values represent an increase of 33.3% for Cr in the potato (minimal), to 6422.5% for Zn in the drumstick (maximal), in terms of the metal contents in the vegetables grown along the channel (figs 10-25). Though table 2 gives the percentage increase in the contents of various metals in 10 different vegetables grown along the channel, the average percentage increase in the channel vegetables is Cu- 646%, Cr- 354%, Zn- 1011%, Ni- 145%, Pb- 975%, Cd- 309% and Fe- 206%. It is clear that the channel vegetables contain

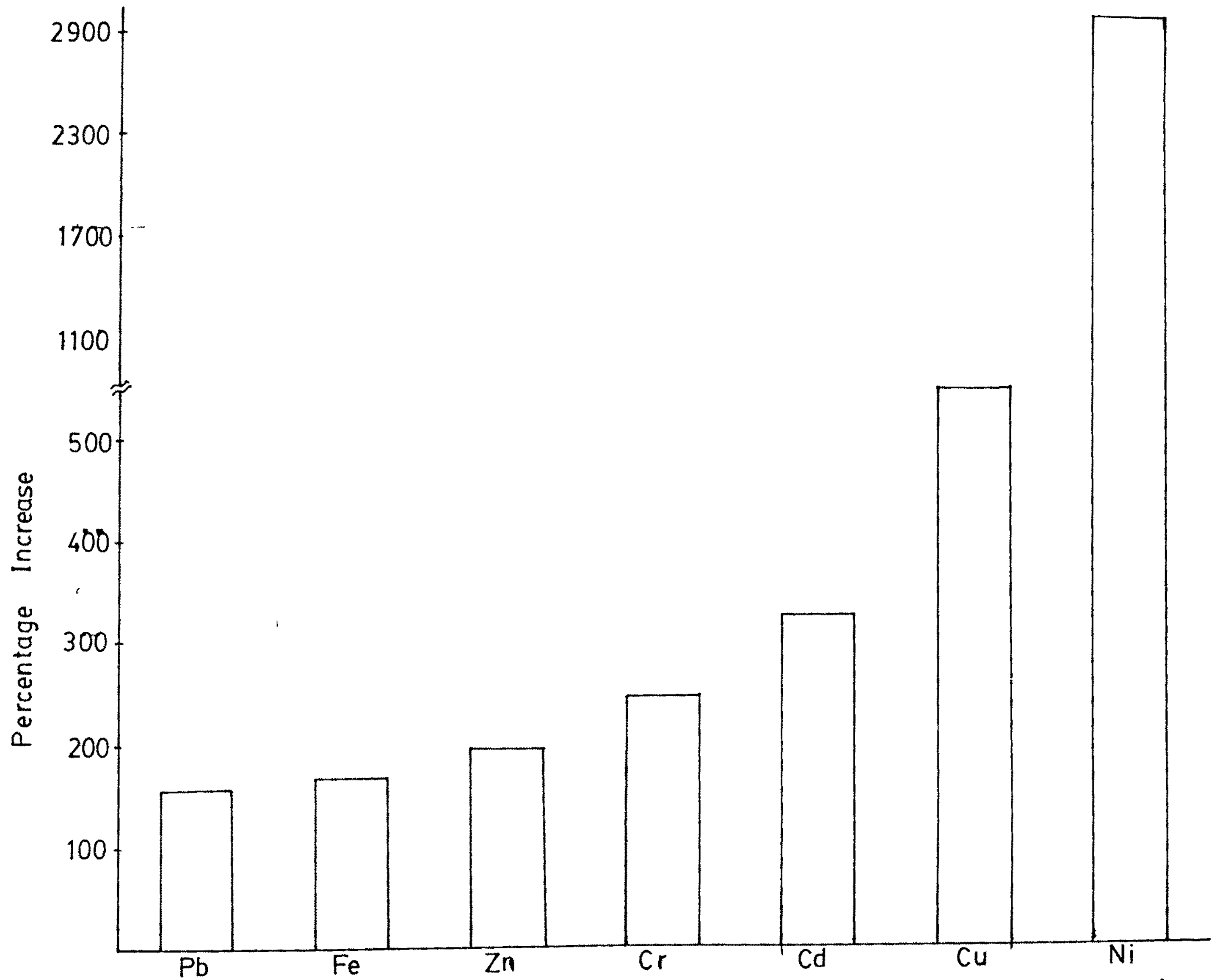

Fig 10 Percentage increase of various metals in maize grown along the effluent channel.

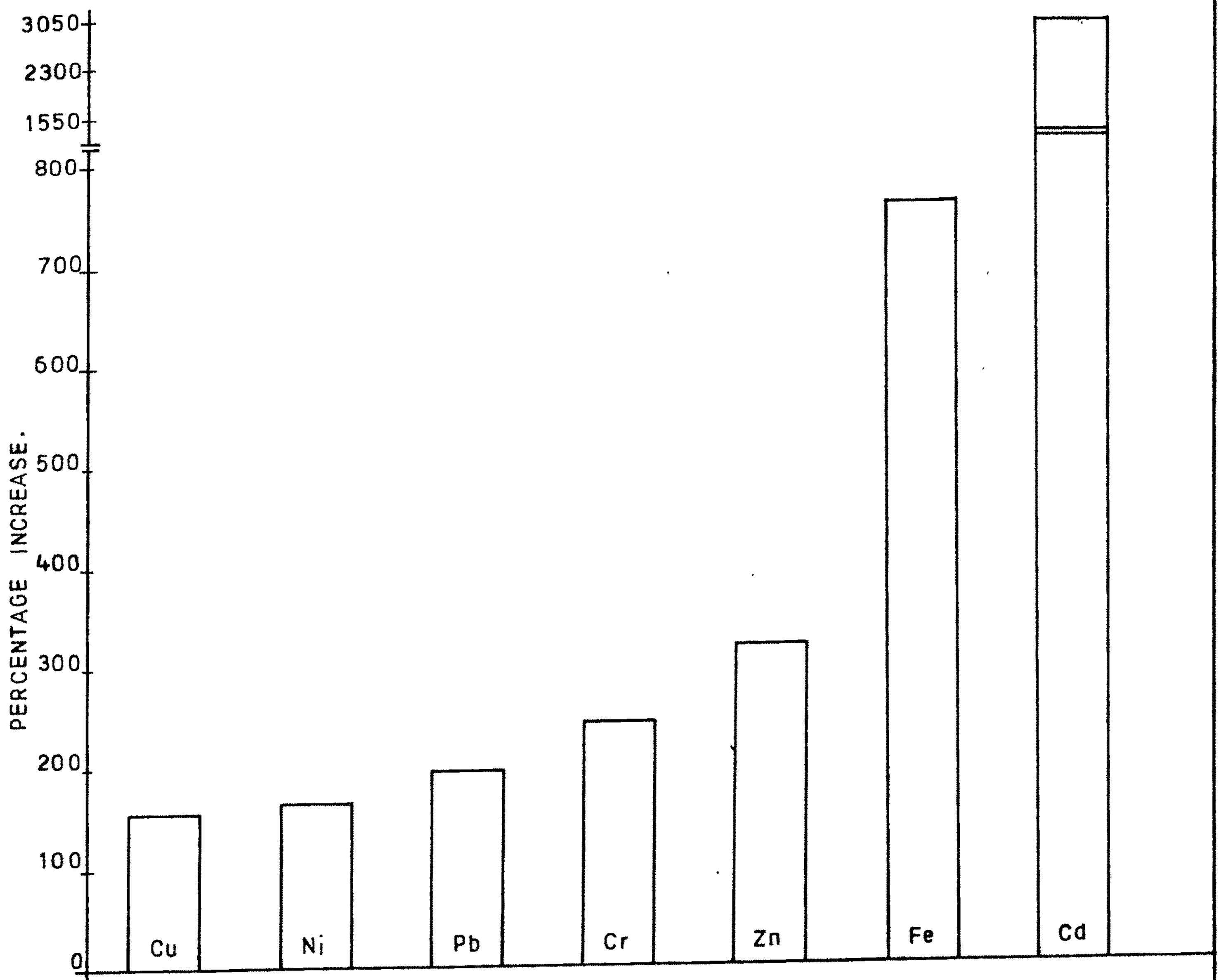

Fig. 11 Percentage increase of various metals in wheat grown along the effluent channel.

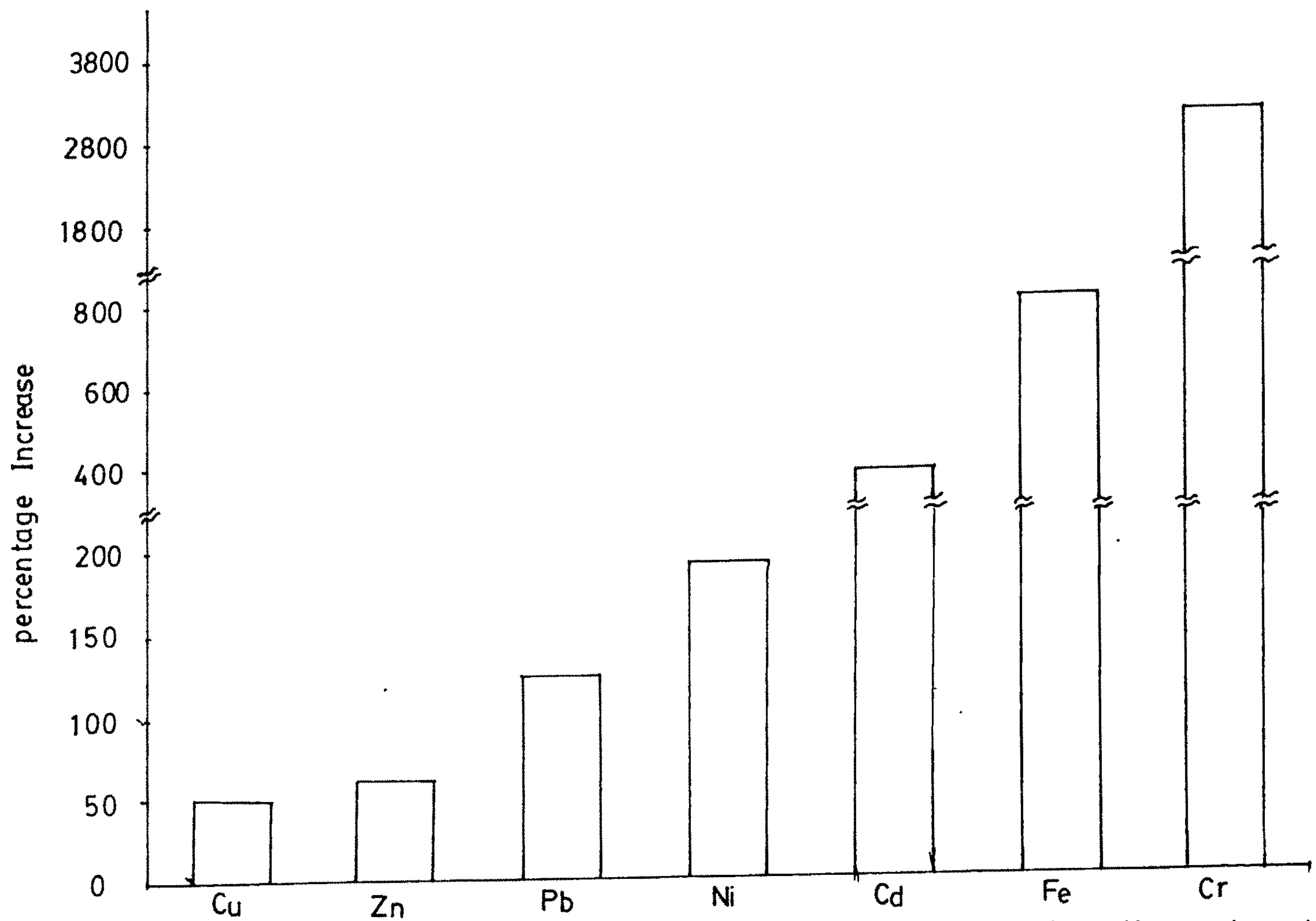

Fig12 Percentage Increase of various metals in bajara grown along the effluent channel.

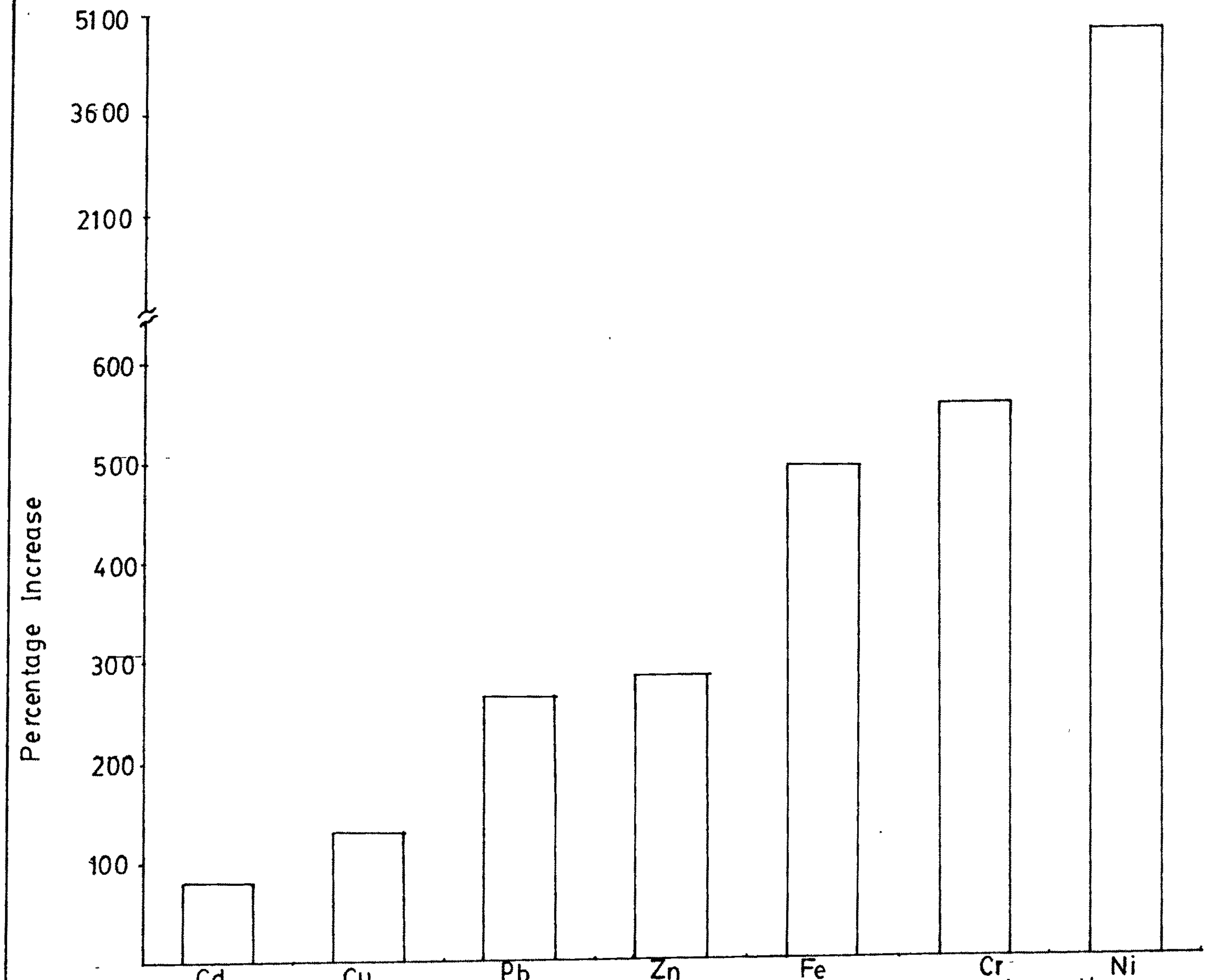

Fig13 Percentage increase of various metals in tuar daal grown along the effluent channel.

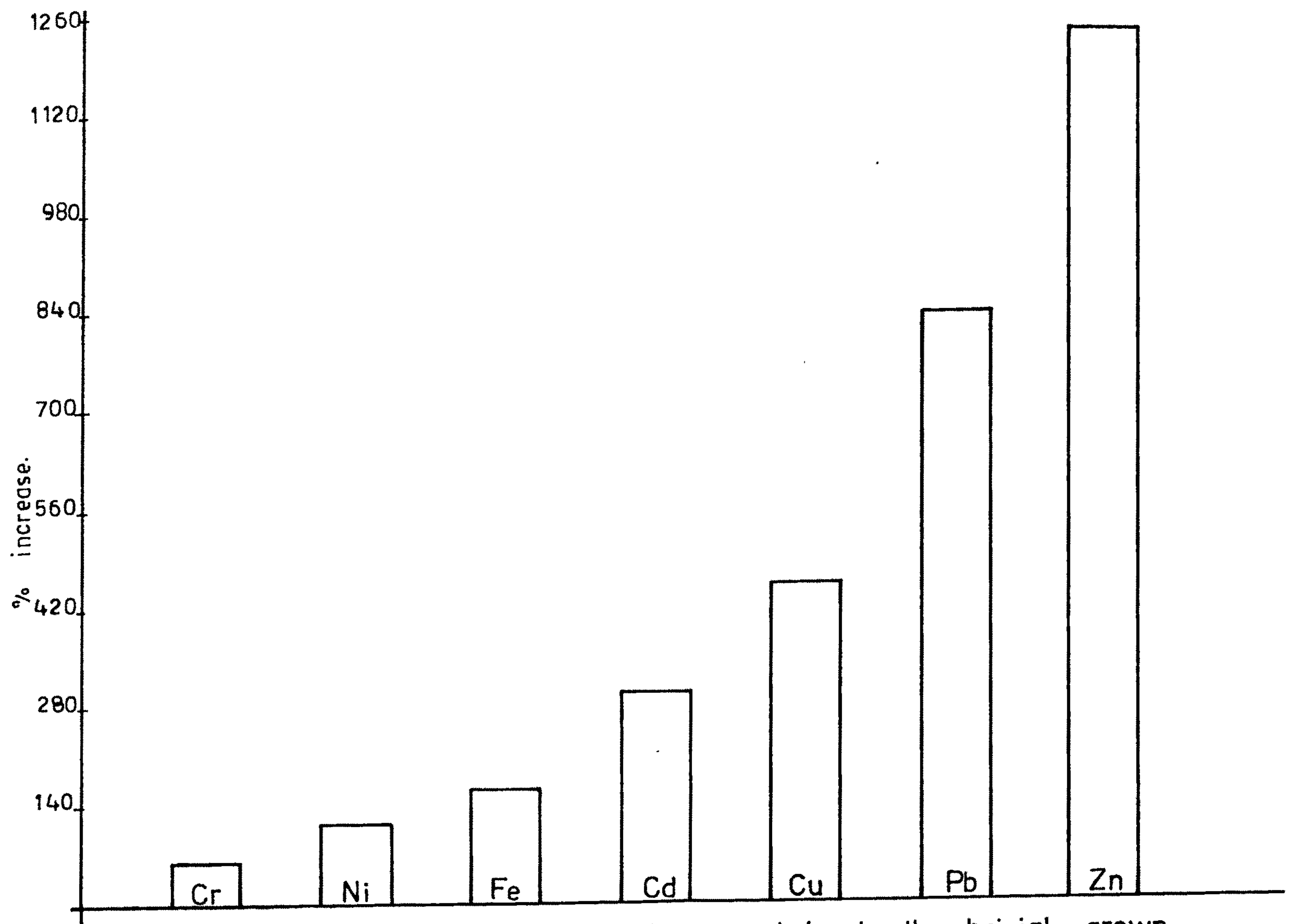

Fig 14 Percentage increase of various metals in the brinjal grown along the effluent channel.

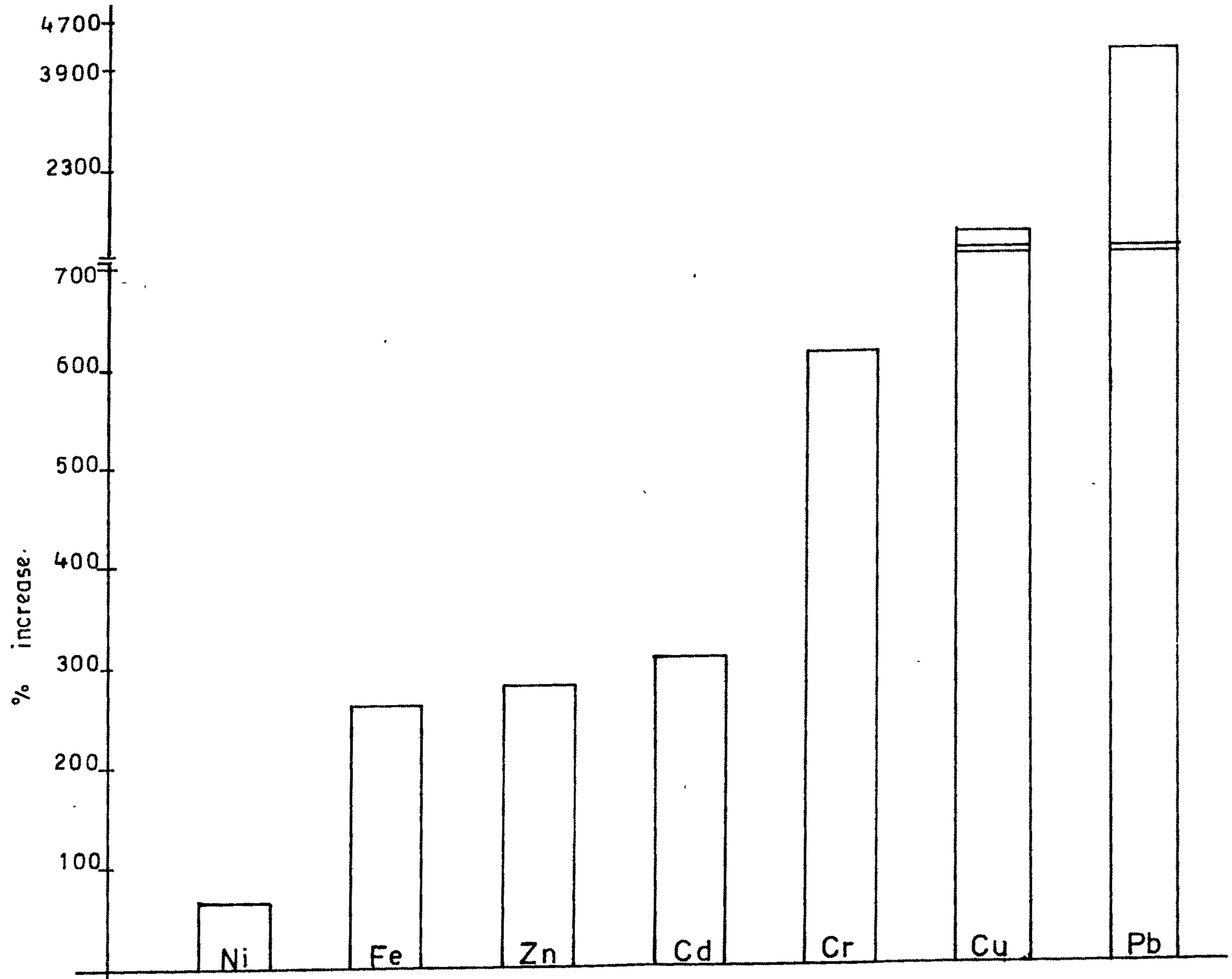

Fig 15 Percentage increase of various metals in cabbage grown along the effluent channel.

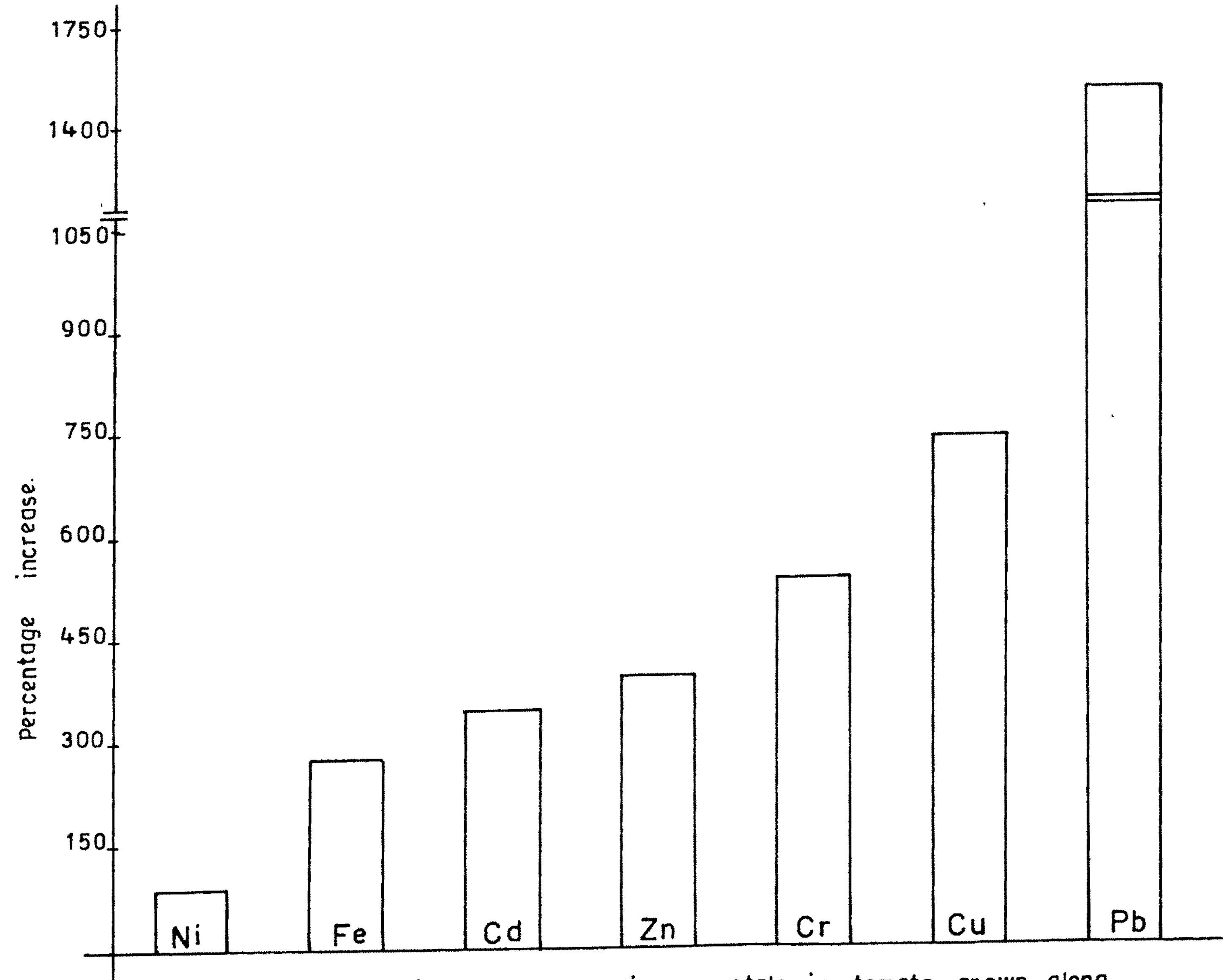

Fig 16 Percentage increase of various metals in tomato grown along the effluent channel.

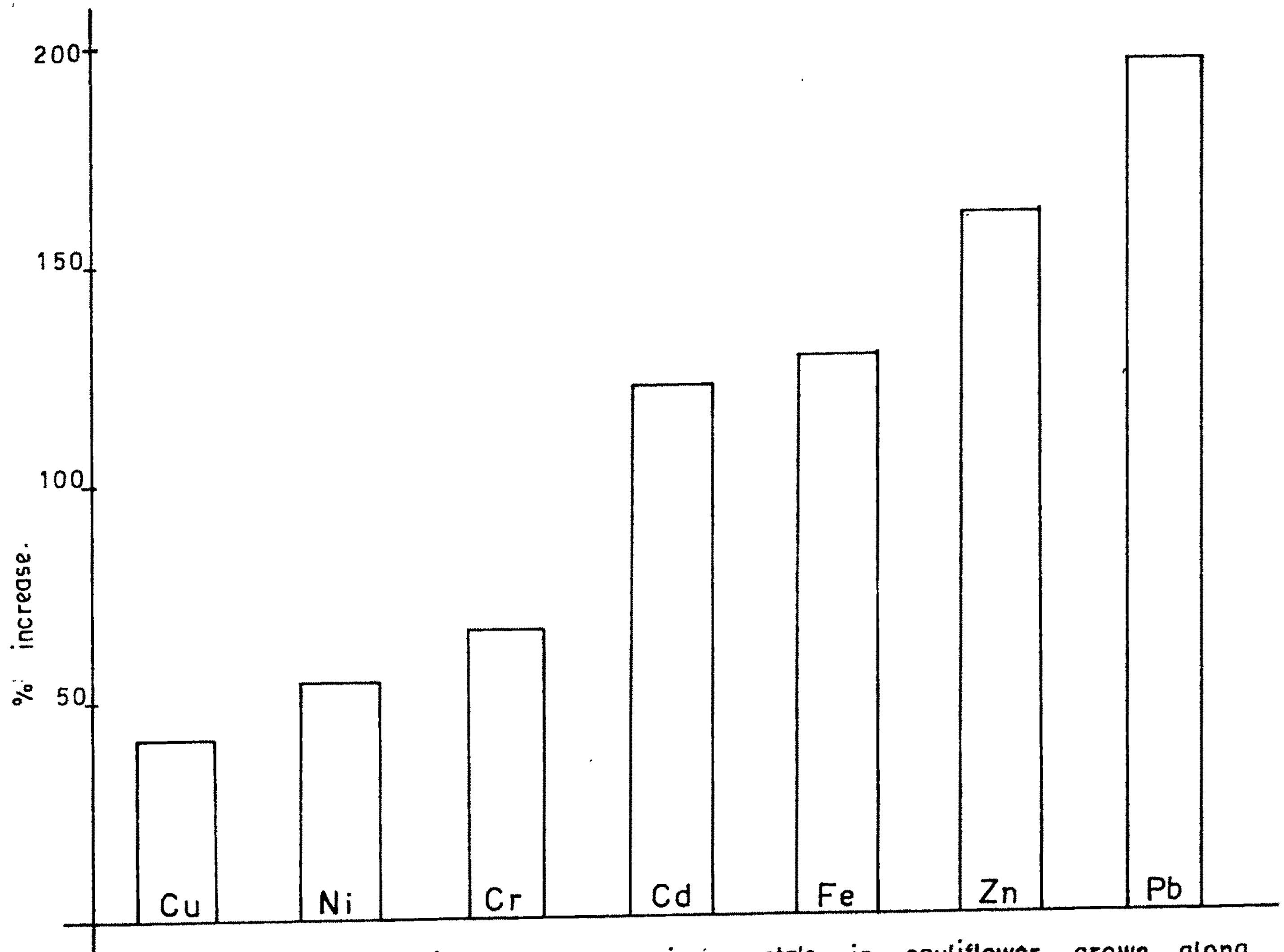

Fig 17 Percentage increase of various metals in cauliflower grown along the effluent channel.

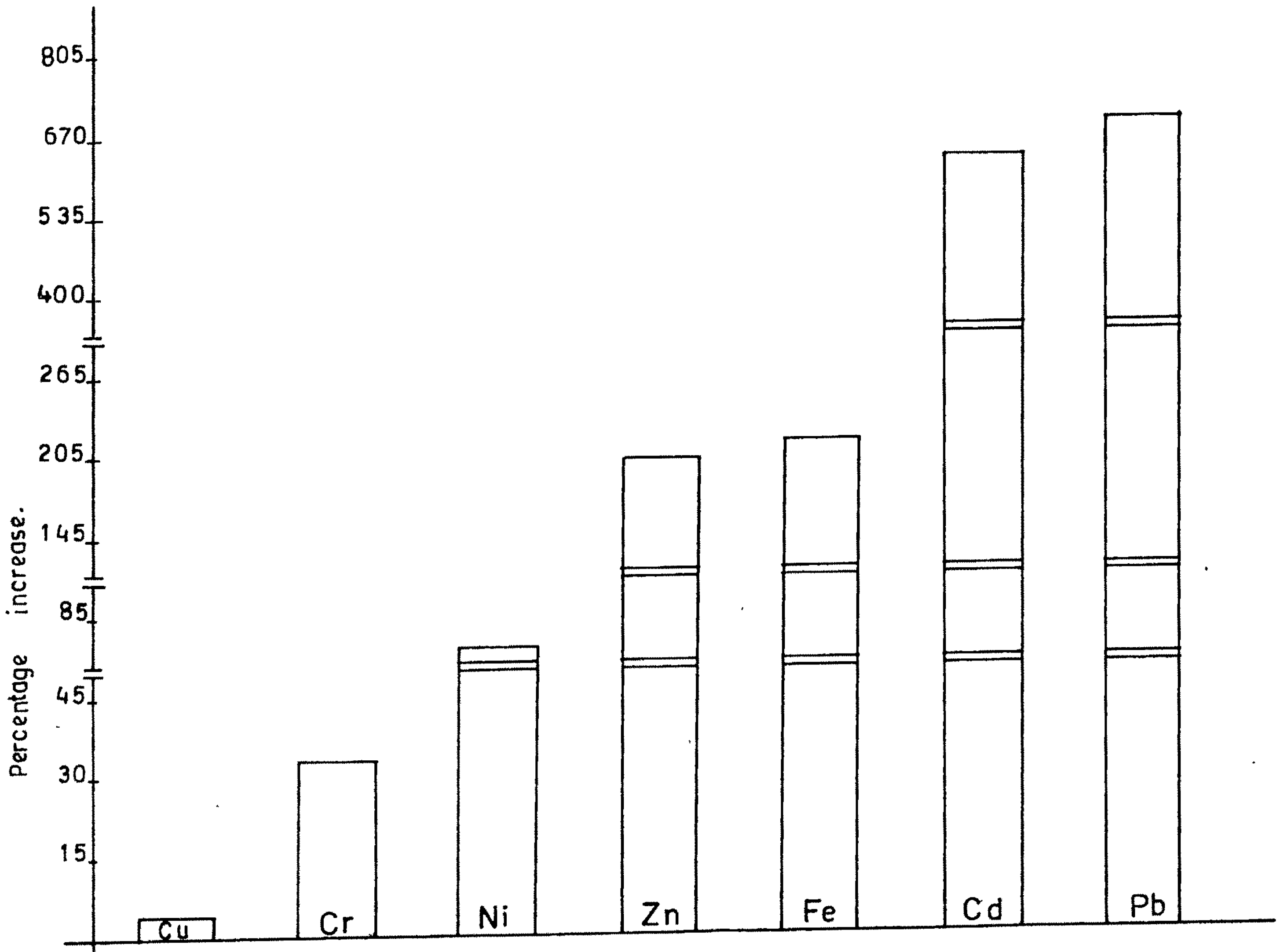

Fig 18 Percentage increase in various metals in potato grown along the effluent channel.

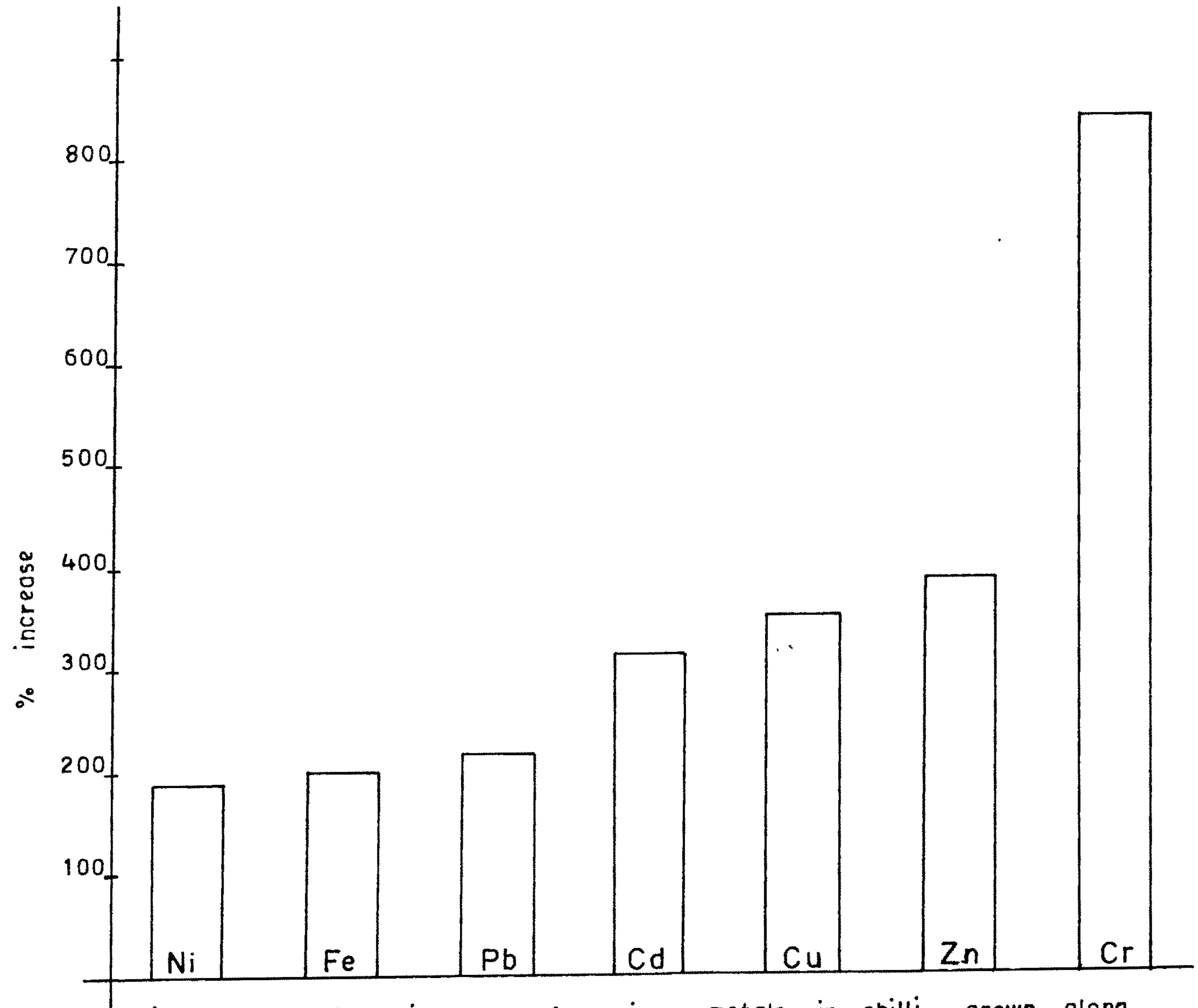

Fig 19 Percentage increase of various metals in chilli grown along the effluent channel.

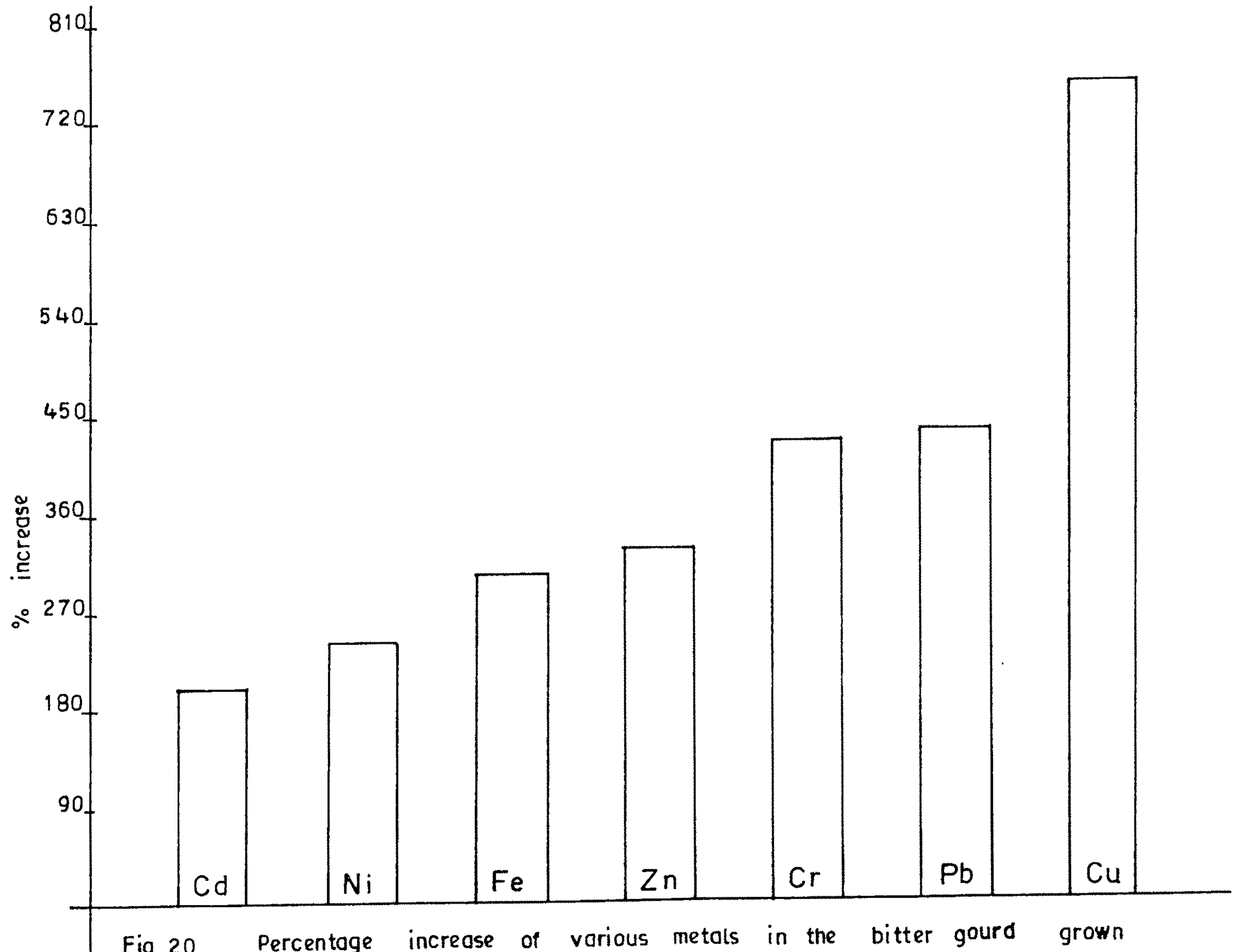

Fig 20 Percentage increase of various metals in the bitter gourd grown along the effluent channel.

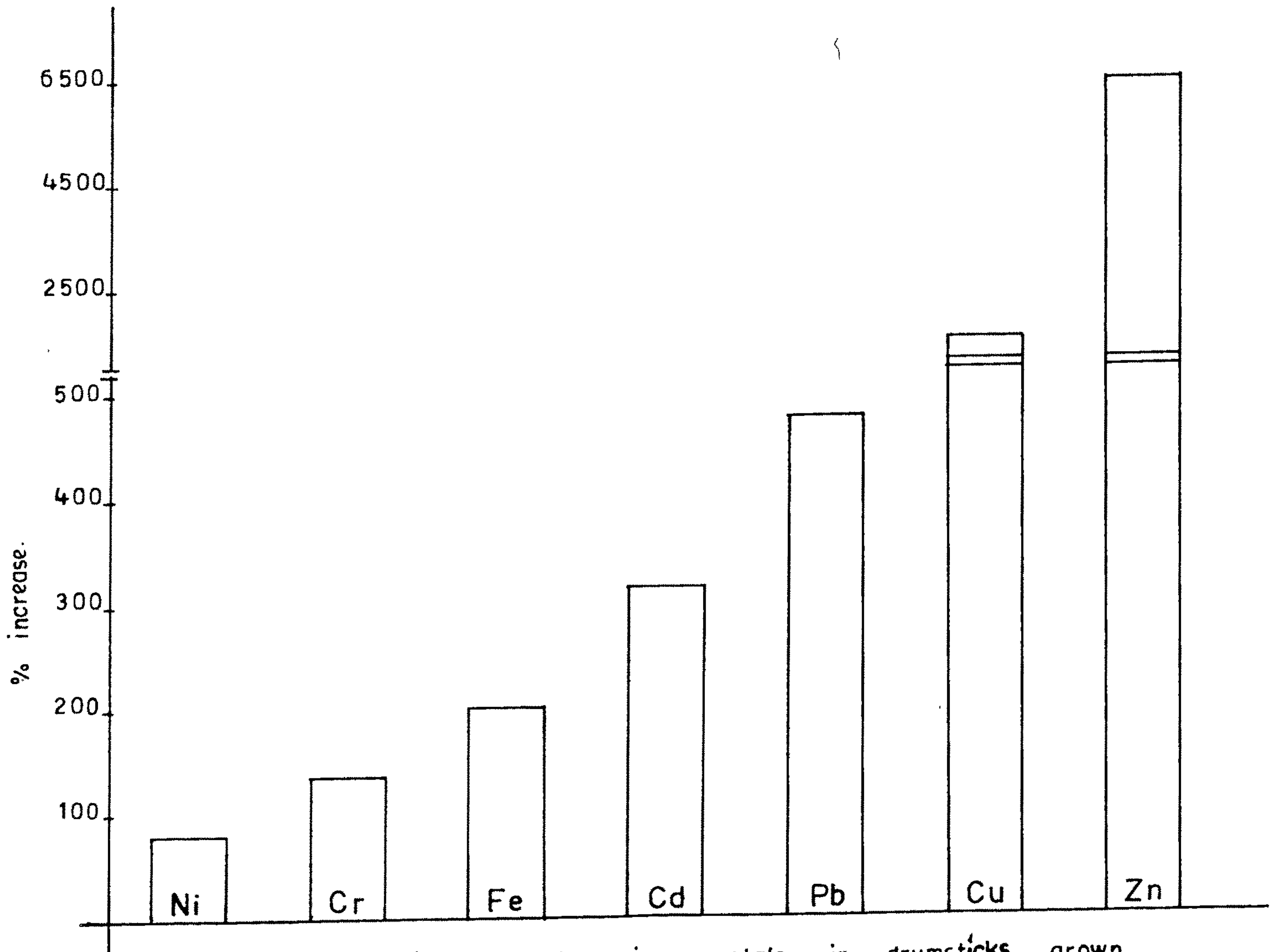

Fig 21. Percentage increase of various metals in drumsticks grown along the effluent channel.

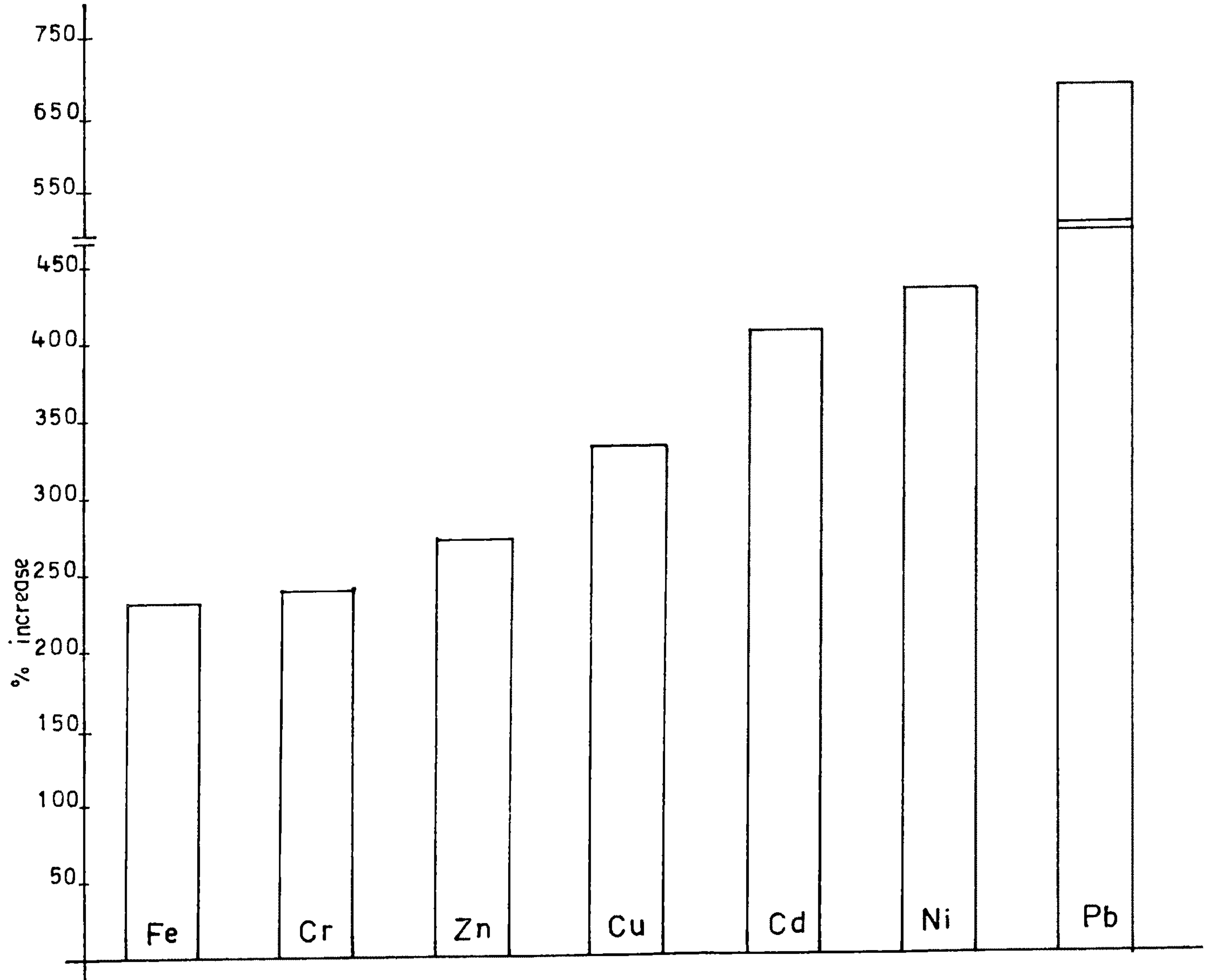

Fig 22 Percentage increase of various metals in geeloda grown along the effluent channel.

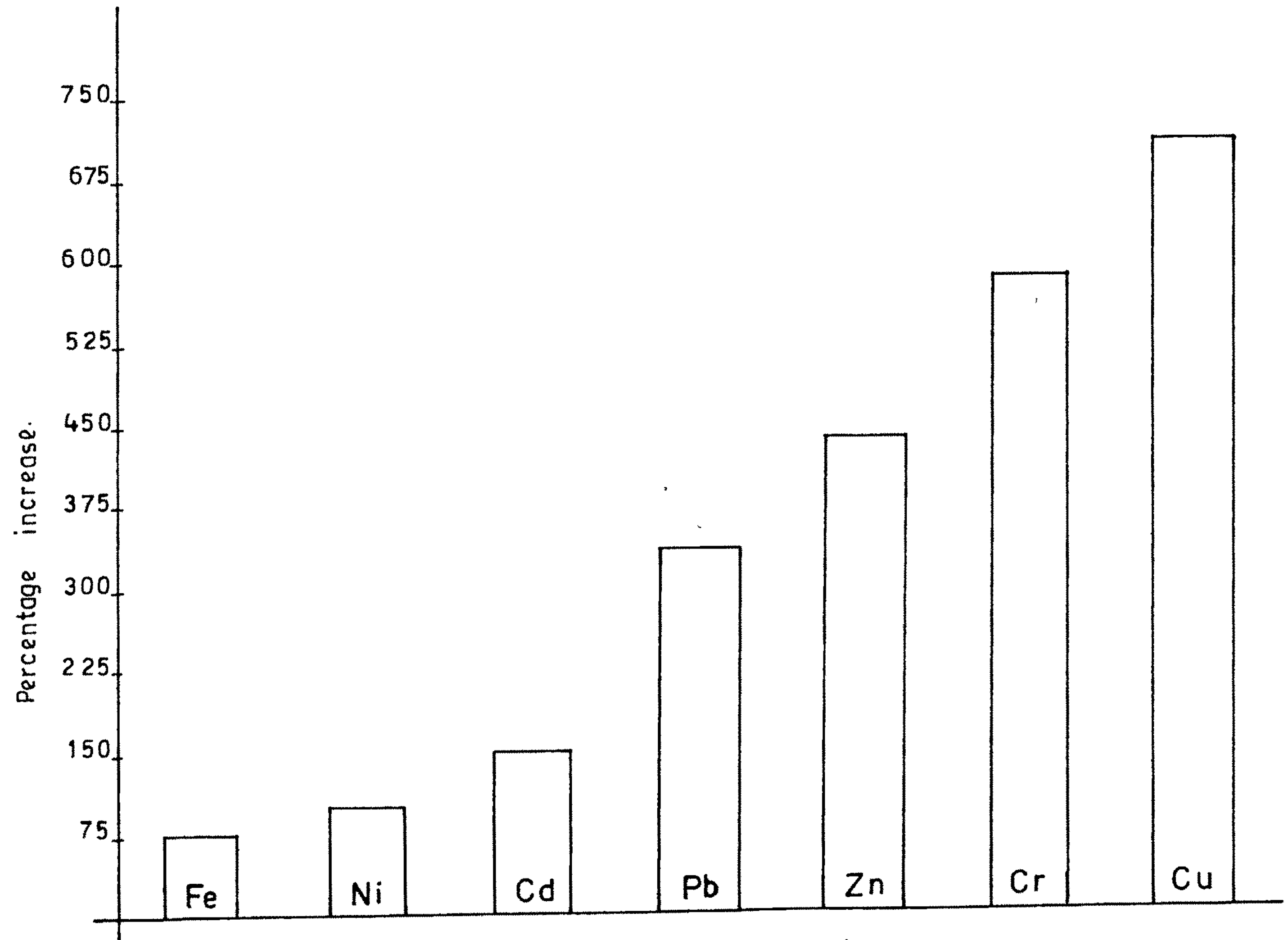

Fig 23 Percentage increase of various metals in green peas grown along the effluent channel.

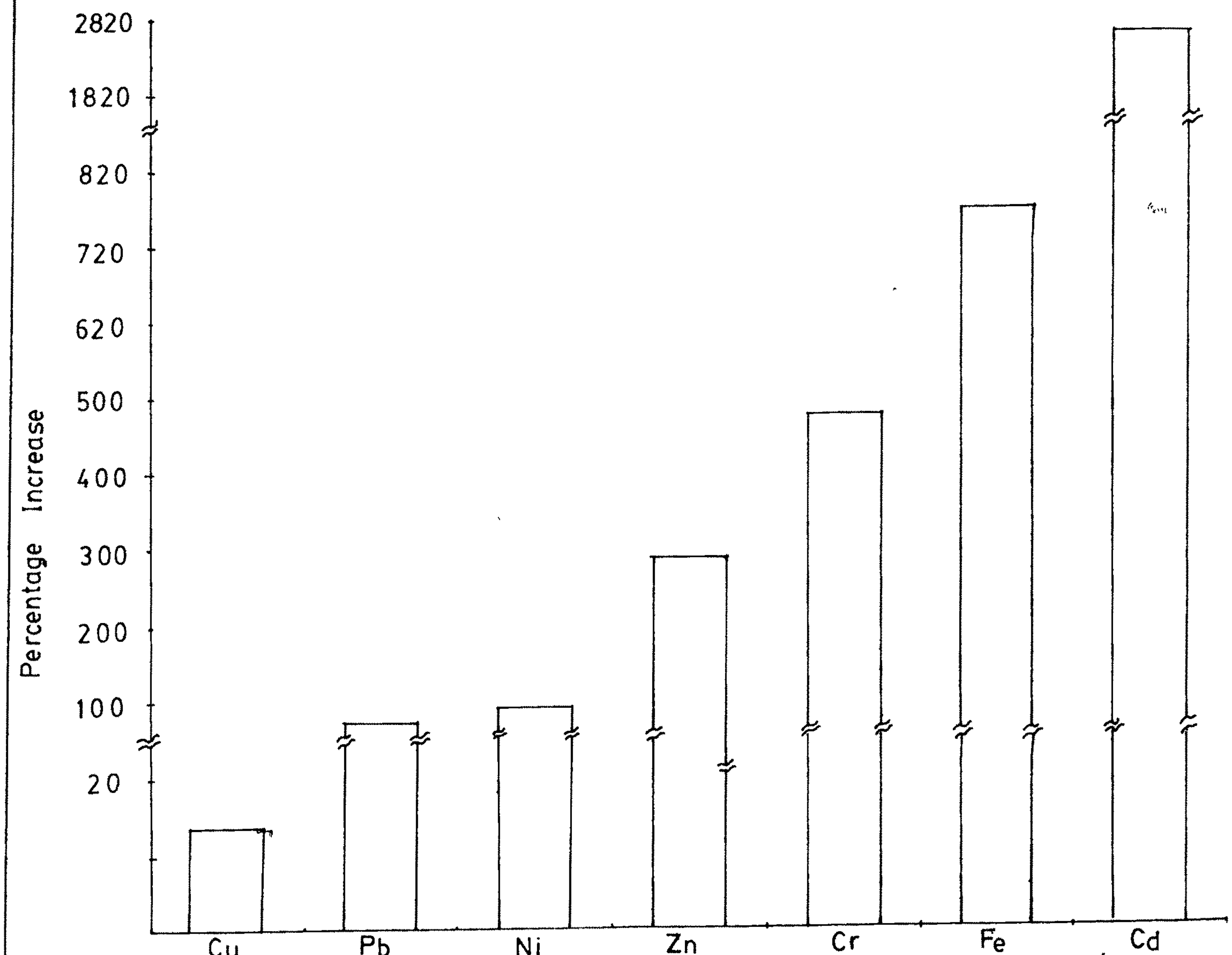

Fig 24 Percentage increase of various metals in tobacco leaves grown along the effluent channel.

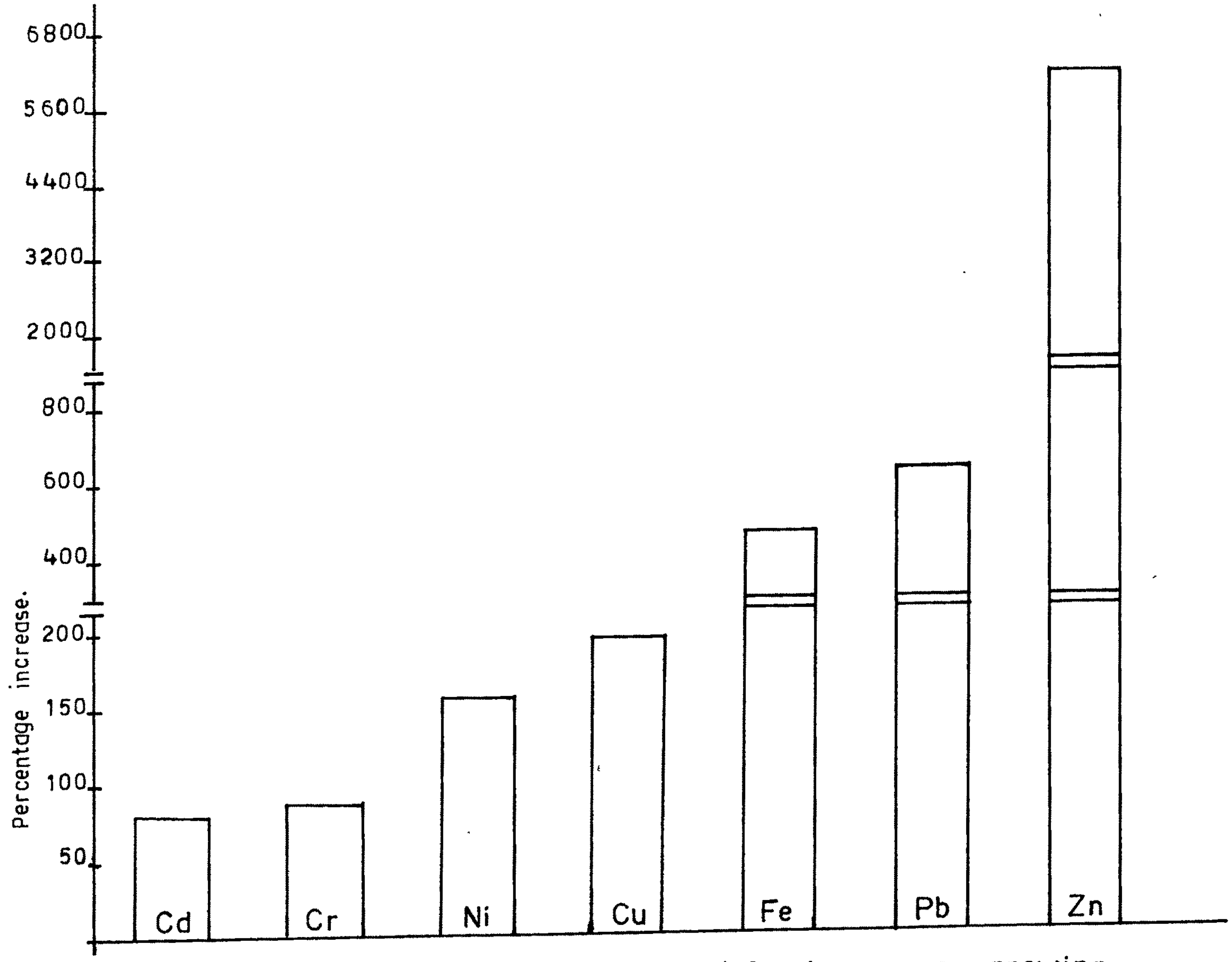

Fig. 25 Percentage increase of various metals in grass growing along the effluent channel.

alarmingly higher levels of all metals. The National Institute of Nutrition (NIN,1981) reported the trace element content (in ppm) in green leafy vegetables (curry leaf, corriander, mint leaf, amarnath leaf, colocasia leaf, drumstick leaf, mesta leaf, etc.) in the range of 16 to 95 for Zn, 1.9 to 18 for Cu, and 0.52 to 3.37 for Cr and, in other vegetables like brinjal, cucumber, beans, pumpkin, raw mango, and bitter gourd, in the range of 5 to 46 for Zn, 0.87 to 11 for Cu, and 0.28 to 4.8 for Cr. Though the above reports of NIN do not differentiate between polluted and non-polluted areas, but is an actual distribution of metals in the vegetables from different parts of the country, it is presumable that the lower ranges represent non-polluted areas and the higher ranges potentially polluted areas. Even then, the content of metals recorded in the present study in the vegetables grown along the effluent channel is much higher than what is reported by NIN.

Like in the case of vegetable, the content of metals in cereal grains, is significantly higher in the channel areas than in the non-channel areas. The increase range between a minimum of 15% for Cu in Bajara to a maximum of 4820% for Ni in tuver and 3060% for Cr in bajara. The reported higher contents of Zn, Cr and Cu in the wheat (NIN, 1977, 1987), is lower than what is observed in the present study in the cereal grains grown along the effluent channel. Remarkably, the metal content in tobacco and grass in the channel area is much higher than in the non-channel areas. On a percentage basis, the increase in the metal content of tobacco leaves was 111% for Ni (minimal) and 2517% for Cd (maximal). Likewise the percentage increment in grass was 72% for Fe (minimal), and 702% for Cu (maximal). Eva (1993) has shown differential content of Cd, Pb and Cu in rice grown in two different areas of Canada. The content of metals obtained in the present study in bajara, wheat, maize and tuar show similar differential distribution, with the grains of channel area showing much higher content than in those of other areas. Apparently, the metal contamination in the grain grown along the effluent channel is much significant in the context of human health. The negative correlation drawn between the Cu content and the total soluble carbohydrates and proteins in rice (Eva, 1993), bespeak of the reduced nutritive value of the cereal grains with increasing metal pollutant load. In this context, the currently observed higher content of metals in the cereal grains grown in the fields irrigated by the channel water, would imply a much reduced nutritive value as well.

The accumulation of metals in vegetables and cereals can in general be considered proportionate to the metal load in the soil. Though this seems to be true for some of the metals, the data recorded in the present study on percentage increment in the vegetables and grains of channel areas reveal even a disproportionate content (Figs 26-32). Accumulation in proportion to the soil load seen with reference to some metals, finds favourable support from the study of Mustfa - Moavad and Obukhov (1992) showing translocation of Cu to corn plants proportionate to the soil load. However, the disproportionate uptake shown by some plants suggest some mechanisms for preferential accumulation. Such preferential accumulation of Zn and Cu over Cd and Pb has been reported for corn (Joe *et al.*, 1992) and has been explained as due to differential absorption by vascular transfer cells. The above study also demonstrated very little effect of the soil content and type in metal accumulation in corn. It is conceivable therefore, that the accumulation of metals by plants can be either proportionate to the nominal load or even disproportionate, depending upon the plant type. Besides the academic and pristine interest of these observations, the most glaring aspect is the disturbing trend of damage to soil ecosystem by the high metal load in the channel areas (ever increasing at an alarming rate with continuous use of channel water for irrigation) and, their accumulation in vegetables and cereals. Consumption of these vegetables and grains by man and domestic animals can lead to biomagnification and poses a great health risk to both man

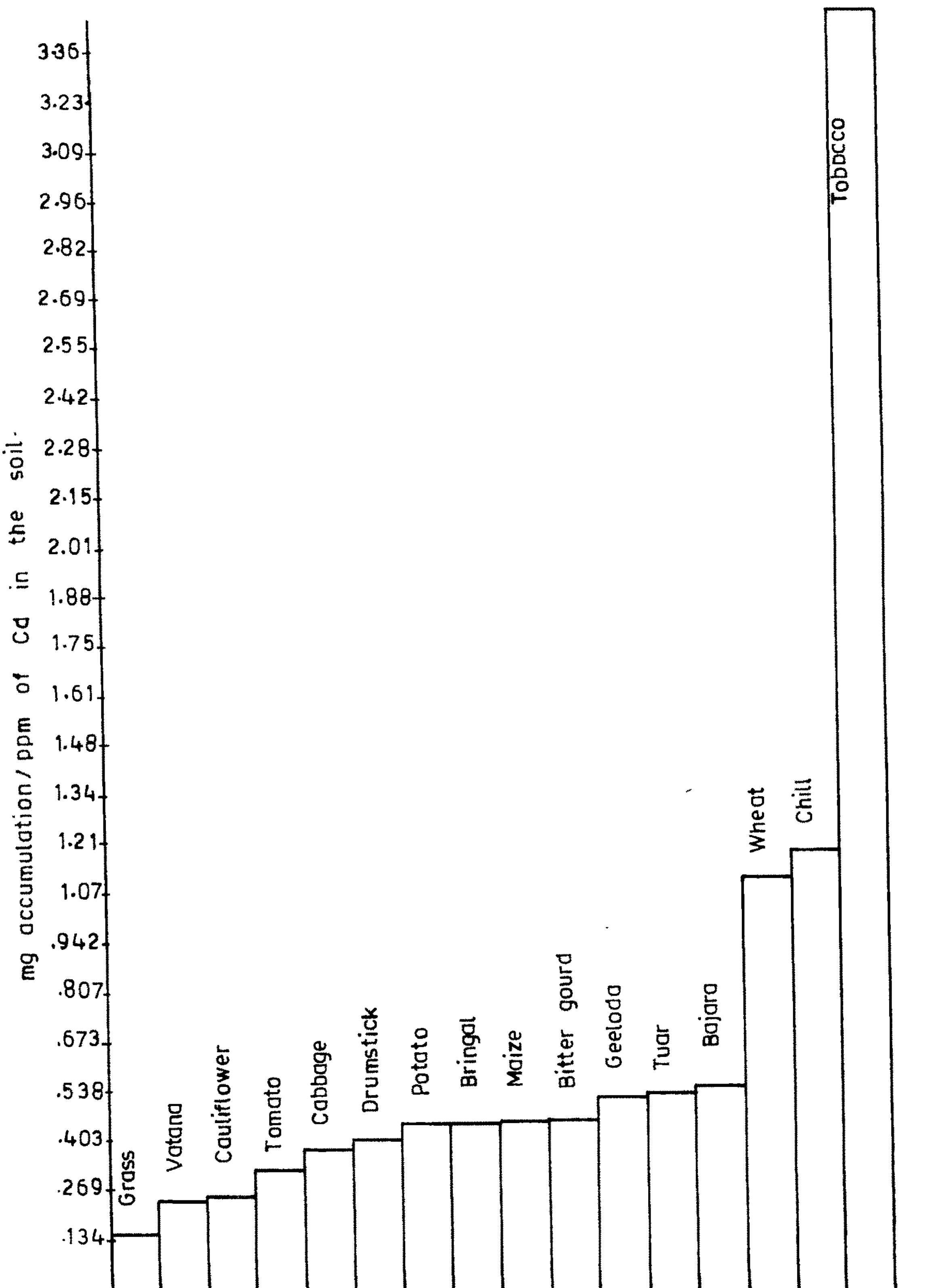

Fig 26 Amount of Cd accumulated by individual vegetable/pulse/cereals/tobacco/grass per unit (1ppm; mg/kg) in the soil.

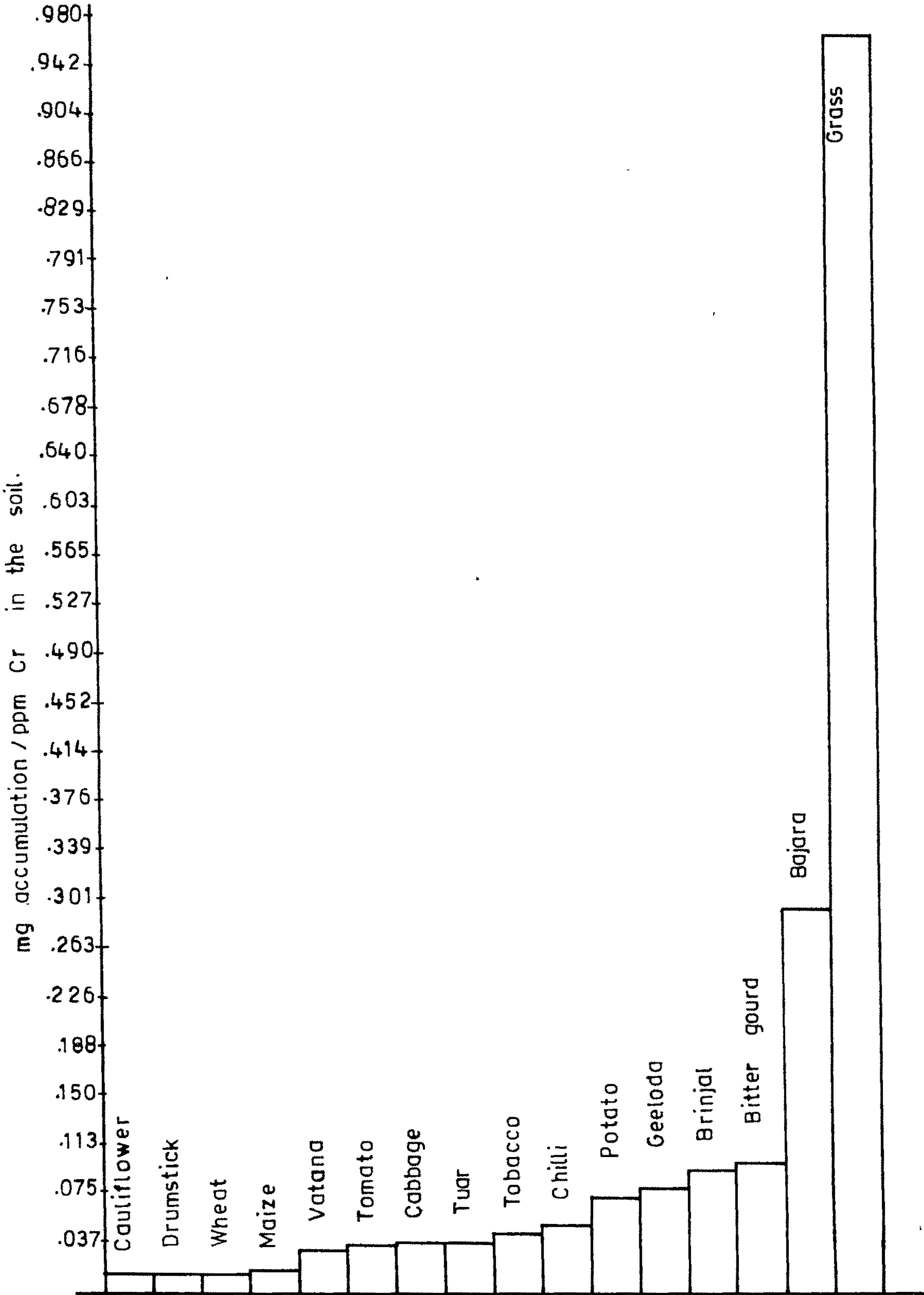

Fig 27 Amount of Cr accumulated by individual vegetable/pulses/cereals/tobocco/grass per unit content (1ppm; mg/kg) in the soil.

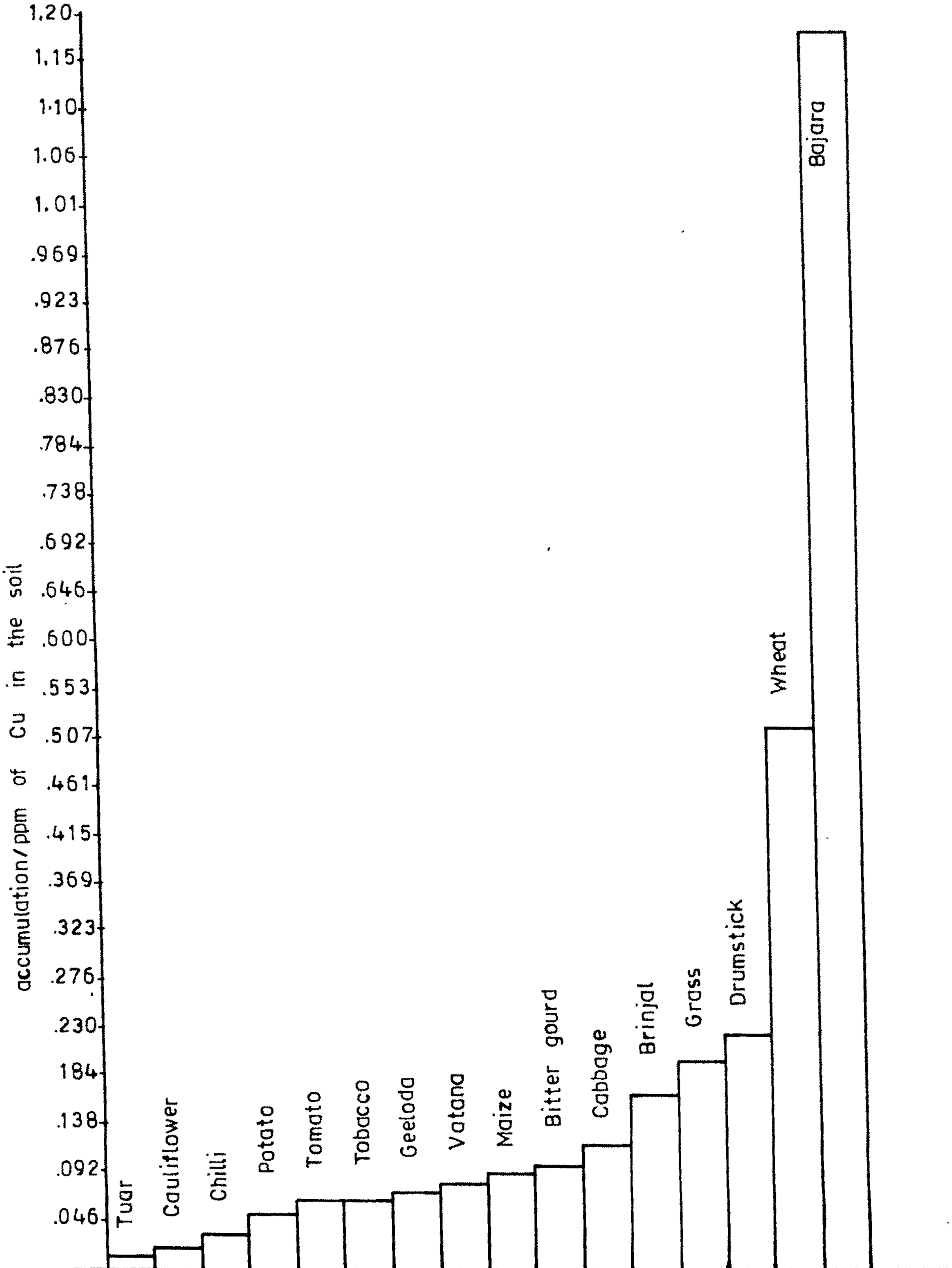

Fig 28 Amount of Cu accumulated by individual vegetable/pulses/cereals/tobocco/grass per unit content (1 ppm; mg/kg) in the soil.

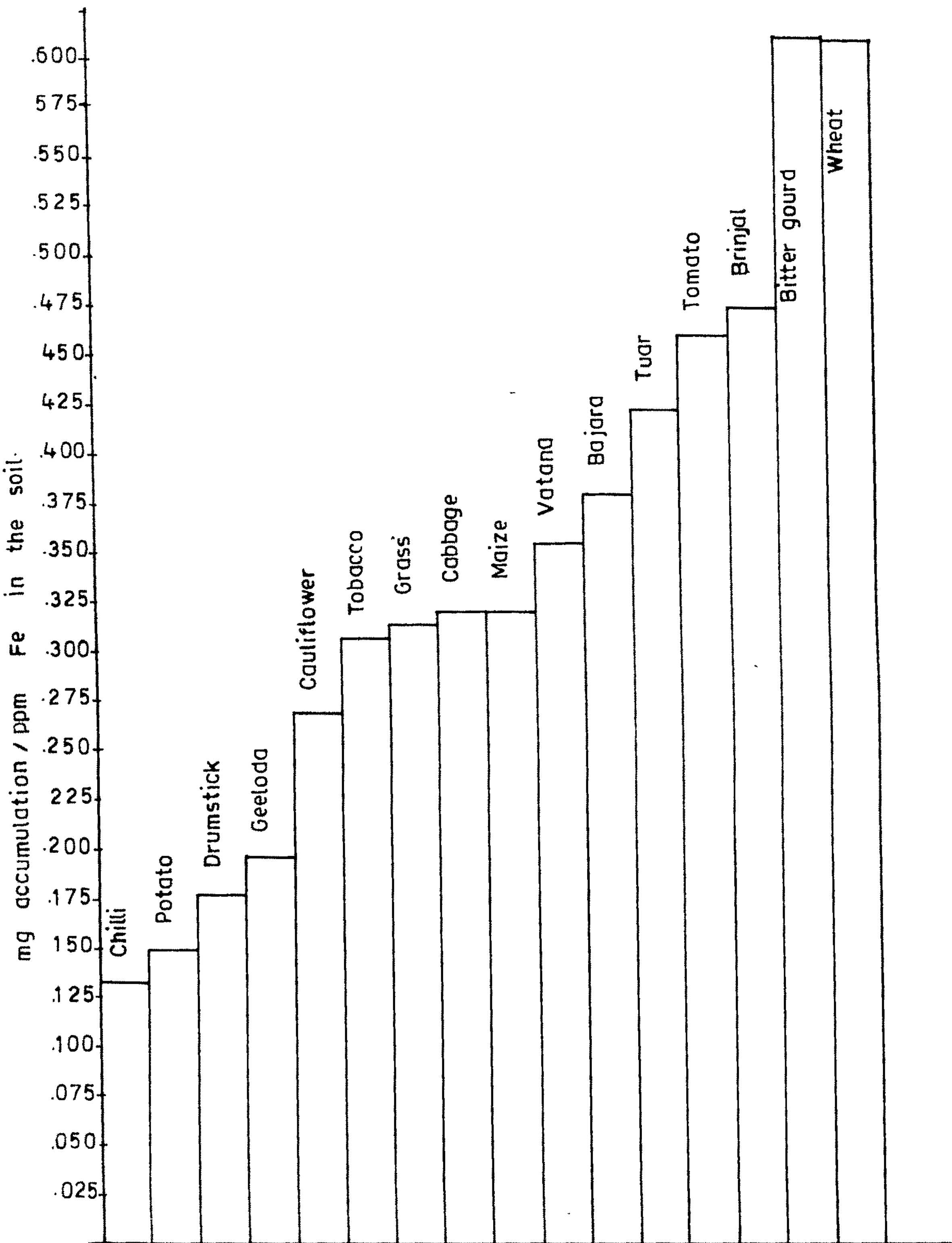

Fig 29 Amount of Fe accumulated by individual vegetable/pulse/tobacco/ grass per unit content (1 ppm; mg/kg) in the soil.

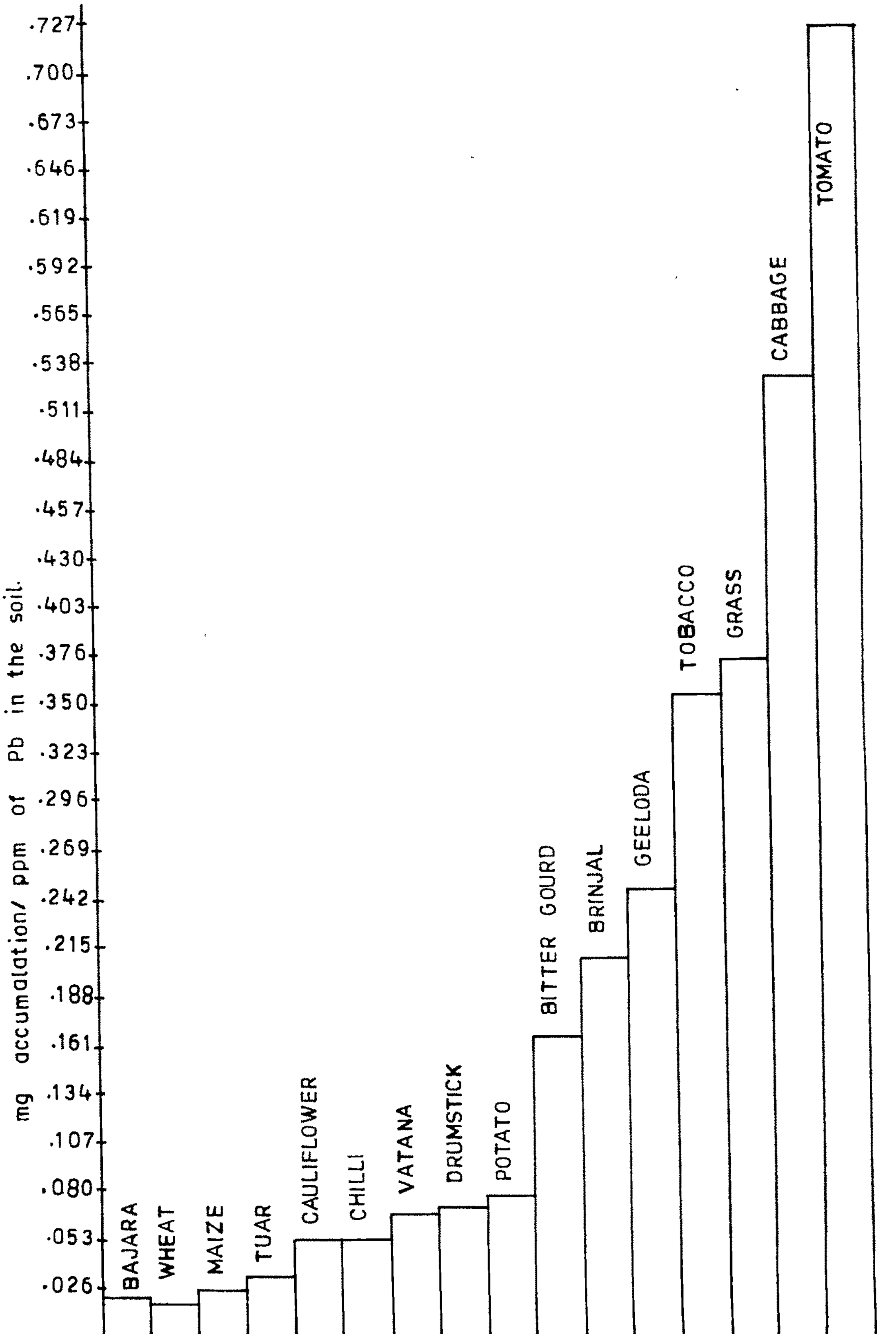

Fig 30 Amount of Pb accumulated by individual vegetable/pulses cereals/tobacco/grass per unit content (1ppm; mg/kg) in the soil.

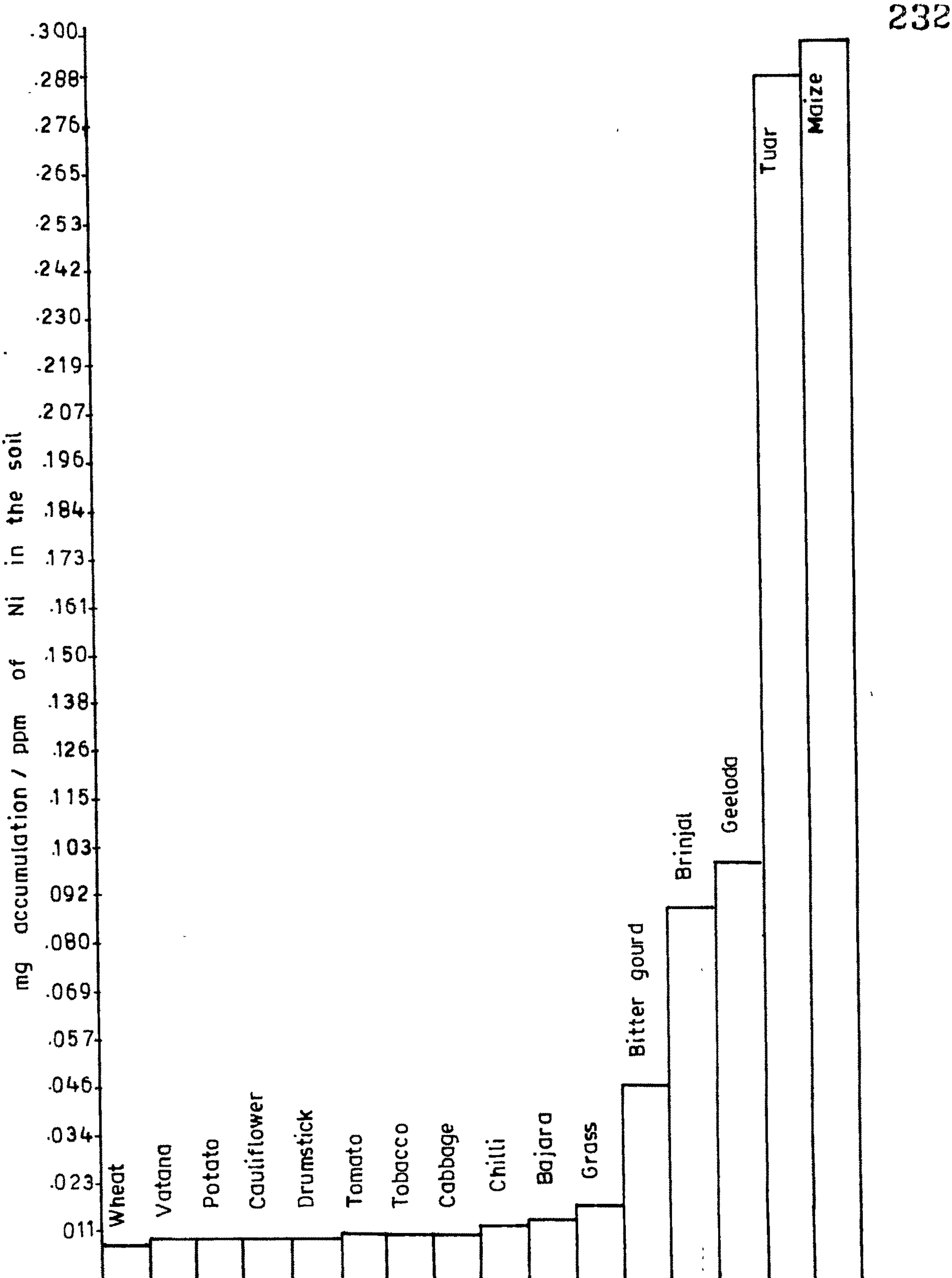

Fig 31 Amount of Ni accumulated by individual vegetable/pulse/cereals/ tobacco/grass per unit content (1 ppm; mg/kg) in the soil.

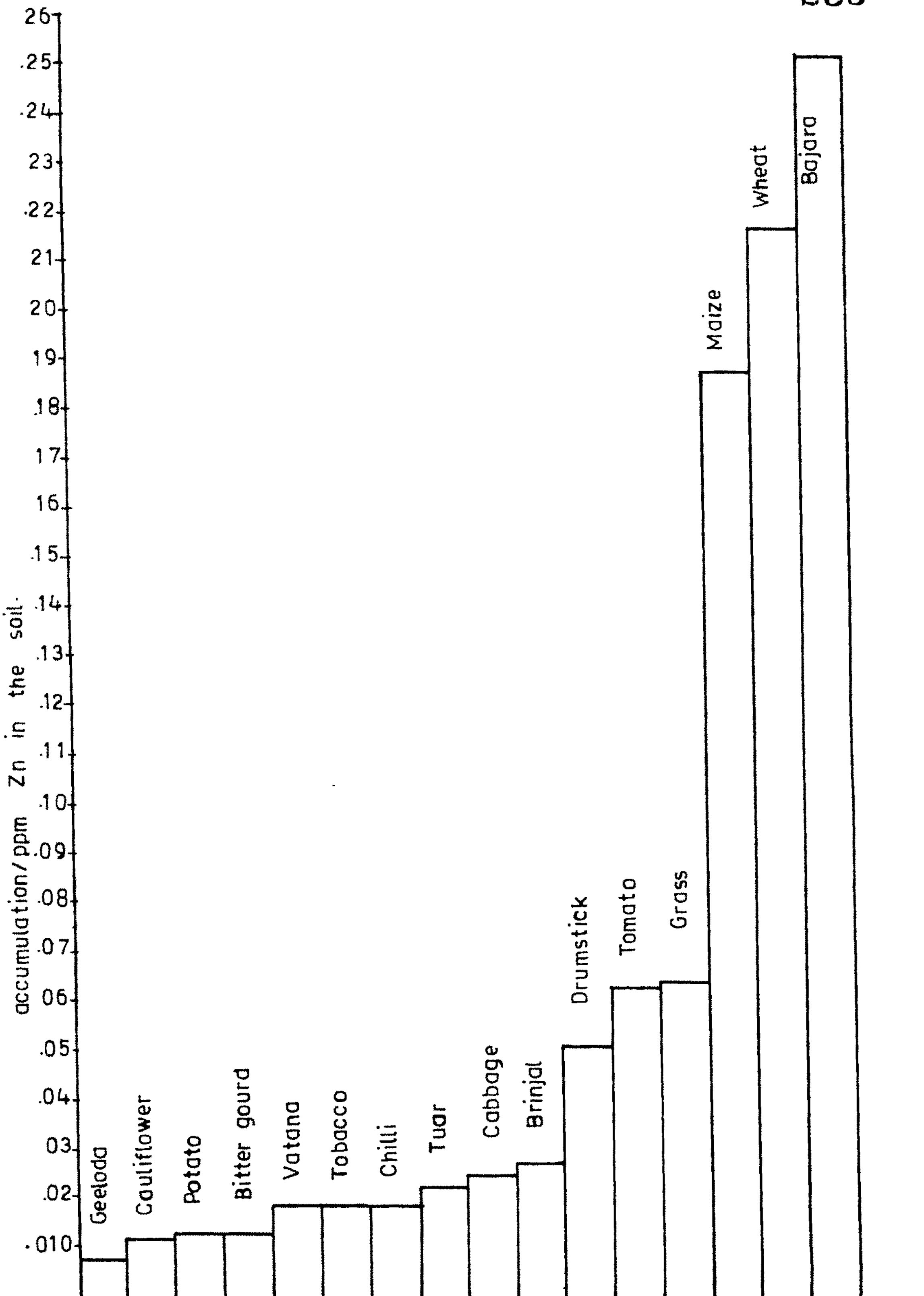

Fig 32 Amount of Zn accumulated by individual vegetable/pulse/cereals/tobacco/grass per unit content (1ppm; mg/kg) in the soil.

and animals. It is ironical that in this era of environmental awareness and protection, we are callously negligent and/or even blissfully unaware of the degree of environmental damage and potential risks to man and animals that are being posed by the effluent channel in Baroda.