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EFFECTS OF ENVIRONMENTAL FACTORS ON NUTRIENTS AND ANTINUTRIENT CONTENTS OF SELECTED LEAFY VEGETABLES

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ABSTRACT

The purpose of this research was to test the hypothesis that plant composition in general, and plant antinutrient content in particular, are affected by environmental factors To test this hypothesis three crops were grown in four benchmark locations which had been characterized for soils and provided with weather stations to monitor air and soil temperatures, relative humidity, rainfall, solar radiation and wind speed The four experimental sites represented four soil series and two soil families The Wahiawa and Lahaina soil series identified on sites on the Islands of Oahu and Molokai were members of the clayey, kaolinitic, isohyperthermic family of Tropeptic Eutrustox whereas the Niulii and Kukaiau soil series identified on sites in the Kohala and Hamakua districts of the Big Island of Hawaii were members of the thixotropic isothermic family of Hydric Dystrandepts

Three test crops were used to test the hypothesis amaranth (*Amaranthus gangeticus* L), a crop cultivated for its tender leaves or grain, cassava (*Manihot esculenta* L), a crop normally cultivated for its starchy tubers, and taro (*Colocasia esculenta* L (Schott) a crop normally grown for its underground corms The leaves of all three crops are consumed by people in the warm tropics For this reason the leaves of all three crops were sampled and analyzed to measure the effects of soil and climate variables on oxalate nitrate , and ionic contents of leaves

Amaranth experiments were installed at three sites At each site irrigated and non-irrigated experiments were conducted Within each

irrigation experiment, three fertilizer treatments consisting of (1) a basal treatment of lime, N, P K, bases, and trace nutrients, (2) a N treatment superimposed on the basal treatment, and (3) a P treatment superimposed on the basal treatment, were arranged in a randomized complete block design with three replications Plant tops were harvested at maturity for chemical analyses

Cassava leaves were sampled from ongoing experiments at the four experimental sites Taro leaves were also sampled from ongoing experiments but from only three sites

Soil and climatic factors significantly influenced the chemical compositions of crops These effects differed for each crop Nitrogen plays an important role in controlling the synthesis of oxalate and the accumulation of nitrate in amaranth The highly variable oxalate and nitrate contents in plants grown in environmentally different sites were, to a large extent, due to different soil N contents

Virtually all oxalate in cassava was in the form of calcium oxalate, so that tissue Ca content was an important factor in oxalate formation

In taro, K appeared to be the key factor accounting for the difference in oxalate content among sites

It was concluded from the results of this study that plant compositions can be controlled by management of the environment and crop selection It follows from this conclusion that the nutritional quality of food crops can be measurably improved if more research is directed towards achieving this goal

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LIST OF ABBREVIATIONS

(for Appendices)

AIR1, AIRMAX	Maximum air temperature
AIR1SQ	Square of maximum air temperature
AIR2, AIRMIN	Minimum air temperature
AIR2SQ	Square of minimum air temperature
AIR3, AIRAVE	Average air temperature
AIR3SQ	Square of average air temperature
AIR4	Difference between maximum and minimum air temperature
AIR4SQ	Square of difference between maximum and minimum air temperature
CA	Calcium concentration
CANUPT	Anion uptake
CATUPT	Cation uptake
CAUPT	Calcium uptake
CC-A, C-A	Cation excess
CL	Tissue chloride concentration
CLUPT	Chloride uptake
CNO3	Tissue nitrate concentration
CNO3UPT	Nitrate uptake
DW	Dry weight
K	Tissue potassium concentration
KUPT	Potassium uptake
MG	Tissue magnesium concentration
MGUPT	Magnesium uptake
NA	Tissue sodium concentration
NAUPT	Sodium uptake
NO3N	Tissue nitrate-N concentration
P	Tissue phosphate
PUPT	Phosphate uptake
OX	Total oxalate concentration
OXPRO	Total oxalate production
OX2	Soluble oxalate concentration
OX2PRO	Soluble oxalate production
OX2-3	Sum of soluble and insoluble oxalate concentration
OX2-3PRO	Sum of soluble and insoluble oxalate production
OX3	Insoluble oxalate concentration
OX3PRO	Insoluble oxalate production
RF	Cumulative rainfall
RFSQ	Square of rainfall
RHAVE RH3	Average relative humidity
RHMAX, RH1	Maximum relative humidity
RHMIN RH2	Minimum relative humidity
RH4	Difference between maximum and minimum relative humidity

RH1SQ	Square of maximum relative humidity
RH2SQ	Square of minimum relative humidity
RH3SQ	Square of average relative humidity
RH4SQ	Square of the difference between maximum and minimum relative humidity
SOLCA	Soil calcium content
SOLK	Soil potassium content
SOLMG	Soil magnesium content
SOLNA	Soil sodium content
SOLP	Soil phosphate content
SOLTN	Soil total nitrogen content
SOL1	Maximum topsoil temperature
SOL1SQ	Square of maximum topsoil temperature
SOL2	Minimum topsoil temperature
SOL2SQ	Square of minimum topsoil temperature
SOL3	Average topsoil temperature
SOL3SQ	Square of average topsoil temperature
SOL4	Difference between maximum and minimum topsoil temperature
SOL4SQ	Square of the difference between maximum and minimum topsoil temperature
SOL5	Maximum subsoil temperature
SOL5SQ	Square of maximum subsoil temperature
SOL6	Minimum subsoil temperature
SOL6SQ	Square of minimum subsoil temperature
SOL7	Maximum subsoil temperature
SOL7SQ	Square of maximum subsoil temperature
SOL8	Difference between maximum and minimum subsoil temperature
SOL8SQ	Square of the difference between maximum and minimum subsoil temperature
SR	Solar radiation
SRSQ	Square of solar radiation
SSAVE	Average subsoil temperature
SSMAX	Maximum subsoil temperature
SSMIN	Minimum subsoil temperature
SUPT	Sulfate uptake
TN, TOTALN	Tissue total nitrogen
TNUPT	Total nitrogen uptake
TSAVE	Average topsoil temperature
TSMAX	Maximum topsoil temperature
TSMIN	Minimum topsoil temperature
WIND, WSP	Wind speed
WSPSQ	Square of wind speed

CHAPTER I

INTRODUCTION

Agricultural practices and research have been geared toward high production to cope with the high rate of increase in world population The genetic characteristics that have led to yield improvements were mainly dwarfism and leaf erectness in cereals, such as wheat and rice These key genetic characteristics gave birth to the green revolution in the 1960s A third characteristic photperiod insensitivity made it easy to fit the short, erect high yielding varieties into a wide range of environments Other genetic traits including resistance to diseases and insects, and tolerance to environmental stress continue to increase yields

Besides genetic factors, cultural factors are also another means employed by agronomists to increase yields These include fertilizer application and irrigation

Low consumer acceptance of several promising high yielding varieties compelled plant breeders to include factors that affect consumer preference into their breeding strategy In addition, some cultural practice has been implemented with the dual purposes of increasing yield and improving quality with regard to consumer preference for example heavy applications of nitrogen fertilizer in order to increase yields and to produce green and succulent produce

Quality is therefore often measured in terms of consumer preference However, preference alone does not ensure food quality The nutritional value of an agricultural product is not always apparent to the consumer More elusive quality factors are the antinutrient and toxic agent contents of food crops Their effects on the consumer are often slow and insidious

Food compositions tables are used indiscriminantly to identify and quantify the nutrients present in various foodstuffs, in spite of their knowledge of the high variability in nutrient contents among cultivar of food crops and among similar crops grown in different places The source of variability could be genetic and/or environmental and cultural With regard to environmental factors growers need to know the environmental factors that affect food quality

This study was based on the hypothesis that variance in nutritional quality of food crops is strongly influenced by cultural and environmental factors

The type of food crops selected for this study were leafy vegetables because they are important sources of oxalate (an antinutrient) and nitrate (a toxic agent) which are nutritionally significant

Vegetables are important sources of vitamins and minerals essential for humans and animals Some of them are also an unconventional source of protein recommended for the tropics where meat is relatively scarce However some vegetables, such as amaranth (Amaranthus species), cassava leaves (Manihot species), taro leaves (Colocasia species) purslane (Portulaca oleracea L) and ungchoi (Ipomoea aquatica) of the tropics, and spinach (Spinacea oleracea L), rhubarb (Rheum rhaponicum) beet (Beta vulgaris) of the temperate regions contain high levels of antinutrient oxalate Oxalate is considered an antinutrient because it can render some mineral nutrients unavailable by binding them to form insoluble salts which are not absorbed by the intestine Many vegetables also contain high content of nitrate which is a toxic agent to humans and animals

The main interest in oxalate is its complex formation with calcium (Ca) to form insoluble Ca-oxalate both within plants and the human body This precludes the utilization of Ca Furthermore high level of soluble oxalate and free oxalic acid can combine with Ca from other foods, further reducing Ca availability in diets

There exist relationships between oxalate and nitrate contents in plants and factors of the agroenvironment These include soil nutrient status, temperature soil moisture, and intensity and duration of radiation Such knowledge has prompted the idea of reducing the content of these two compounds in plants by manipulating agroenvironmental factors The most widely researched factor is perhaps plant nutrient supply For example, different forms of nitrogen fertilizers affect the oxalate and nitrate contents in plants differently While nitrate fertilizer tends to increase oxalate and nitrate contents in plants, ammonium fertilizer tends to decrease them

Cation-anion balance is a sound concept to explain the presence of oxalate in plants It was proposed that organic acids (including oxalate) were produced to balance excess cations In this way, any external factors which can exert influence on the content of cation excess in plants should in turn affect oxalate content

Amaranth, taro and cassava chosen for this study contain high levels of oxalate and are widely consumed as vegetables in the tropics Amaranth is also gaining popularity in the continental U S as a leafy vegetable

This study was undertaken to investigate the effects of agroenvironmental factors on the production of oxalate and nitrate in these tropical vegetables in the hope that the additional knowledge and understanding gained would lead to ideas as to how these factors can be managed to produce high quality vegetables with regard to their contents of oxalate and nitrate The objectives of this study are, therefore as follows

1 To assess the contribution of soil and climate variables to the variance in oxalate and nitrate contents of food crops

2 To ascertain the relationship between cation-anion balance and the biosynthesis of oxalate

3 To identify practical measures to control oxalate and nitrate contents of food crops

CHAPTER II

REVIEW OF LITERATURE

This study draws upon two disciplines agronomy and human nutrition Agronomy deals with understanding and manipulating genotype by environment interactions to optimize food production whereas human nutrition deals with understanding and optimizing human health through nutrition The relationship being considered is primarily between agro-environment and the nutritional quality of food crops Inferences are made on the relationship between plant, and man to some extent

Oxalate and nitrate content, as well as the content of other nutrients of leafy vegetables were chosen as plant parameters that may be affected by soil and climatic factors Oxalate and nitrate were selected for study because they are an antinutrient and a toxic agent respectively to humans They are also present in many leafy vegetables consumed in the tropics Moreover, earlier studies indicate that there is a definite relationship between plant tissue nitrate content and agroenvironment Comparable studies on oxalate, on the other hand are scarce

The background information forming the basis for this study is presented and includes the relationships among agroenvironmental factors and oxalate and nitrate contents in plants, the mechanism of oxalate synthesis, and the accumulation of oxalate and nitrate in vegetables

2 1 Antinutirient oxalate and toxic agent nitrate in foods

Antinutrients are chemical substances (natural or synthetic) that can inhibit nutrients from performing their normal functions

Antinutrients can be divided into 3 groups according to the mechanisms by which they inhibit nutrient function

1 Those that bind nutrients chemically and make them unavailable for absorption by the digestive system Examples of antinutrients are oxalate which binds Ca and phytate which binds trace elements, such as Fe Zn and Cu These antinutrients lower the nutritional quality of food with respect to minerals, because the nutritional quality is determined by the proportion of absorbable and utilizable essential elements in a meal (Mertz, 1980, Quarterman, 1973 as cited by Welch and House, 1984)

2 Those that compete with nutrients for intestinal absorption sites

3 Those that compete with nutrients for biological (enzymic) reaction sites For example, antivitamins such as isoniazid (a tuberculosis drug), which competes with pyridoxine (vitamin B_6)

Antinutrients that bind nutrients (group 1) do so in the food before it is ingested and/or in the body Oxalic acid belongs to this group of antinutrients

Oxalic acid ($H_2C_2O_4$) is a relatively strong dicarboxylic acid Like other acids oxalic acid can be converted into salts This property is important for this study because oxalic acid becomes an antinutrient when it forms insoluble salts with nutrients such as Ca and Mg Hodgkinson (1977) has described the properties of various oxalate salts in detail Of particular interest are the oxalate salts of Ca Mg K, Na and ammonium (NH_4) that are frequently encountered in plants

Oxalic acid forms neutral and acid salts with monovalent cations including ammonium With most divalent cations it forms only one salt Potassium forms three salts, a neutral and acid salt and a tetraoxalate (Hodgkinson, 1977)

Except for the salts of the alkali metals (Li, Na, K), ammonium, and Fe III, most oxalates are sparingly soluble in water The most soluble oxalate salt associated with a bivalent metal is magnesium oxalate (MgC_2O_4) and the least soluble among the common oxalates are calcium oxalate (CaC_2O_4) and lead oxalate (PbC_2O_4) All are soluble in strong acids (Hodgkinson, 1977) Knowledge of the solubility of oxalates is important for developing techniques to fractionate oxalates in plants

Oxalic acid becomes an antinutrient when it forms insoluble salts with Ca and Mg However, the potential of it becoming an antinutrient is high when it is in the form of free acids or soluble salts Therefore, assessing food quality with respect o its oxalate contents involves fractionating and identifying the kind of salts and/or free oxalic acid a food contains

Nitrate (NO_3^-) is considered a toxic agent because even though nitrate itself presents no health hazard to human and animal, its derivatives, namely nitrite (NO_2^-) and nitrosamine are health hazards The effects of nitrate on health are discussed in section 2 4

2 2 Oxalate accumulation in vegetables and other plants and its effects on the health of humans and animals

Oxalate exists in plants mainly as water soluble acid soluble (water insoluble) and free acid forms The water soluble forms include sodium- potassium- and ammonium oxalate and the water insoluble forms include calcium- and magnesium oxalate Hodgkinson (1977, p 130) has reviewed the various forms of oxalate in plants For example, the oxalate in *Begonia semperflorens* exists almost entirely as free acid, and sodium salts predominate in *Halogeton glomeratus* Potassium salts predominate in *Oxalis*, *Rumex*, and several Nigerian vegetables, such as *Talmium triangulare* (Oke 1969) Ammonium oxalate appears to be the principal form in the tropical grass, *Setaria sphacelata* and calcium oxalate is found in plants such as beet, spinach, and buckwheat Der Marderosian et al (1980) discovered that almost half of the oxalate in amaranth is in the soluble form Singh and Saxena (1972) found both soluble and insoluble forms of oxalate in six leafy vegetables consumed in India (i e , amaranth [*Amaranthus gangeticus* L], bathua [*Chenopodium album* L] kharbathua [*C murale* L], purslane [*Portulaca oleracea* L] spinach [*Spinacea olearacea* L] and beet [*Beta vulgaris* L]) High correlations were found between the concentration of soluble oxalate and K and Na, and between insoluble oxalate and the sum of Ca and Mg Sap pH has been used to identify high oxalate-producing plants, as sap pH correlates well with the form of oxalate (James 1972 p 232) Two categories of plants are recognized

1 Plants such as *Oxalis pes-caprae* and some species of *Rumex* which have a sap pH of about 2 in which case the oxalate anion is present chiefly as the acid oxalate ($HC_2O_4^-$)

2 Plants of some Chenopodiacae, which have a sap pH of about 6 indicating that the oxalate is present chiefly as the oxalate anion ($C_2O_4^{2-}$)

According to James (1972), the oxalate in the first category of plants is present chiefly as potassium acid oxalate, and the oxalate in the second category is present mainly as soluble sodium oxalate and the insoluble calcium and magnesium oxalates

One of the plants with the highest known oxalate content is *Halogeton glomeratus* (Chenopodiaceae) This plant contains as much as 30% oxalate on a dry weight basis Another high oxalate plant is *Oxalis cernua* (Oxalidiaceae) (Fassett, 1973) In spinach the total oxalate content ranges on a dry weight basis from 5 42% in savoyed-leaf variety to 9 81% in smooth leaf variety (Kitchen et al , 1964a) Fassett (1973) summarizes oxalate contents in various plants, expressed as percent on a fresh weight basis The contents range from 0 3-1 2% in spinach, 0 2-1 3% in rhubarb, 0 3-0 9% in beet leaves, 0 3-2 0% in tea and 0 5-0 9% in cocoa Suvachittanont et al (1973) determined the oxalic acid content of some vegetables from Thailand and reported oxalic acid contents of 3 3% on a dry weight basis (DW) or 0 4% on a fresh weight basis (FW) for *Amaranthus gangeticus* Linn and 0 6% DW or 0 1% FW for cassava leaves According to Standal (1982), the oxalate content of taro leaf (*Colocasia esculenta* var Bun-long) was 0 5% FW

The oxalate content of plants is generally higher in the leaves than the stalk (Fassett 1973) as has been demonstrated in amaranth (Der Marderosian et al 1980) taro (Standal, 1983) and spinach (Kitchen and Burns 1965) Kitchen and Burns (1965) found only trace amounts of oxalic acid in spinach seed They stated that oxalate concentration decreased with increasing distance from the leaves which is assumed to be the site of oxalate production

The probable detrimental effects of oxalic acid and oxalate on human health are as follows

1 According to Suvachittanont et al (1973) ingestion of dilute oxalic acid solution produces little gastrointestinal distress but may cause weakness, muscular twitchings, sometimes convulsions, coma or death

2 It has also been suggested that oxalic acid might play a role in cardiovascular disease (Anderson et al , 1971)

3 A harmful effect, particularly in relation to calcium utilization, has been demonstrated for dietary oxalate For example, Pingle and Ramasastri (1978) showed that in humans, the availability of Ca from a diet of amaranth leaves was very low relative to that from milk In addition, the intake of amaranth leaves together with milk adversely affected the absorption of milk Ca

4 Excessive intake of oxalates in the diet is an etiological factor for the formation of renal and urinary calculi Renal and urinary calculi are known to contain oxalate, especially Ca oxalate In an area in Thailand where urinary bladder stone disease is endemic, local vegetables and forest plants commonly consumed by villagers of all ages contained very high levels of oxalic acid (Valyasevi and Dhanamitta, 1974) Oxalate consumption in Rajasthan, India has been suggested as a cause of the incidence of renal calculi (Singh et al , 1972)

The different forms of oxalate have different implications to human nutrition Insoluble calcium oxalate precludes the utilization of calcium in the intestine Soluble oxalate and free oxalic acid can combine with calcium from other foods and thus reduce calcium availability Hodgkinson has cited work which shows that oxalic acid and soluble oxalates interfere with the intestinal absorption of calcium and that calcium oxalate is poorly utilized (Hodgkinson 1977 p 207)

Oxalate poisoning in animals, especially ruminant animals is well-documented There is ample evidence that many pasture plants and weeds containing oxalate, are poisonous to animals James (1972) gave a thorough and comprehensive review of incidences of oxalate poisoning in animals with an emphasis on oxalate toxicosis According to James (1972), oxalate poisoning in livestock results primarily from the ingestion of plants She gave examples of plants that contain dangerously high levels of oxalate (10% or more anhydrous oxalic acid on a dry weight basis) including Halogeton glomeeratus, greasewood (Sarcobatus vermiculatus) and sugar beet (Beta vulgaris) of the Chenopodiaceae family, soursobs (Oxalis pes-caprae) and the sorrels of the Oxalidaceae family, and certain Rumex species, and docks of the Polygonaceae family Grasses also produce oxalate, but they do so at a lower level than the previously listed forbs and shrubs In the tropical grass Setaria (Setaria sphacelata), in which oxalate poisoning of grazing animals has been reported the oxalate contents of some varieties reach values as high as 4-5% on a dry weight basis (Jones et al , 1970) Pigweed (Amaranthus retroflexus) leaf contains oxalate content as high as 12-30% on a dry weight basis (Marshall et al , 1967) Poisoning and sometimes death have been reported in swine (Osweiler et al , 1969 as cited by James 1972) and cattle (Brown 1974 Stuart et al 1975) ingesting this plant

According to James (1972) most oxalate-producing plants are palatable to livestock, and therefore the husbandry of ruminants with access to these plants becomes critical The extent of damage to livestock can be extensive A case where 1200 sheep were poisoned of which 100-800 died, has been reported Deaths in numbers less than a hundred are common (James, 1972)

James (1972) has described in detail the symptoms of oxalate poisoning and its accompanying pathological changes There appears little doubt that if intake of oxalate from forage exceeds the capacity of rumen decomposition, sheep, cattle, swine and horses may develop serious (acute and chronic) symptoms accompanied by deposition of calcium oxalate crystals in various tissues Furthermore, she pointed out that the response of animals to oxalate intoxication varied with animal species as well as with species of plant consumed This is an indication that the kind and amount of oxalate found in plants affect the health of consumers

2 3 Factors affecting oxalate contents in plants

Factors such as soil fertility, light intensity season, temperature, plant age, and genotype influence the oxalate content of plants These factors can be grouped into broader categories--soil, agroclimate, genetic make up of plants, and stage of growth

2 3 1 The concept of cation-anion balance

The concept of cation-anion balance is the most widely used explanation for the variation in the organic acid concentration of plants (Kirkby and Mengel, 1967 Kirkby 1969 Ismandji and Dijkshoorn 1971, Breteler 1973, Dijkshoorn 1973 Nelson and Selby, 1974 Kirkby and Knight 1977 Peck et al 1980 Israel and Jackson 1982) The concept is based on the assumption that in higher plants the sum of cation including Ca Mg, K and Na (denoted by C) and expressed as cmol

kg^{-1} (me 100 g^{-1}) of dry weight minus the sum of inorganic anion concentrations including NO_3^-, $H_2PO_4^-$ SO_4^{2-} and Cl^- (denoted by A), represents the cations excess (C-A) that should occur as the salts of organic acids (Dijkshoorn, 1962)

The following is an example to illustrate this concept

The results of plant analyses show that

- Sum of cations (Ca^{2+}+Mg^{2+}+K^++Na^+) = 180 cmol kg^{-1}
- Sum of unassimilated anion concentrations ($H_2PO_4^-$+SO_4^{2-}+NO_3^-+Cl^-) = 70 cmol kg^{-1}
- Excess cations = 180 - 70 = 110 cmol kg^{-1}
- Sum of organic anion concentrations (e g malate citrate fumarate, succinate, malonate, quinate oxalate and polyuronate = 110 cmol kg^{-1}

In some plants, such as those in the family Chenopodiaceae and some tropical grasses, oxalic acid predominates (Dijkshoorn, 1973, Zindler-Frank, 1976), but in most other plant species malic acid dominates (Dijkshoorn 1973) About 10-20% of (C-A) is polyuronic acid in cell walls and the remainder being other organic acids (Dijkshoorn 1973)

2 3 2 Soil ionic environments

Soil fertility exerts some effects on oxalate levels of some plants High soil fertility associated with high soil carbon nitrogen available phosphorus and potassium is associated with high total oxalate in *Amaranthus* and *Basella* (Schmidt et al 1971) However differences among species were much greater than differences due to soil fertility

Other studies have shown the existence of a relationship between calcium and oxalate contents in plants Rasmussen and Smith (1961) demonstrated a positive correlation between calcium and oxalic acid in Valencia orange leaves Olsen (1939) suggested that calcium absorption from the soil is related to oxalic acid production in plants Brumagen and Hiatt (1966) found that oxalate interfered with calcium translocation and utilization in tobacco plants They measured more oxalic acid in tobacco varieties that were susceptible to calcium deficiency than in non-susceptible varieties De Kock et al (1973) studied the effect of oxalate on the absorption of calcium in Lemna gibba L and demonstrated that Ca uptake and oxalate production were stimulated in each other s presence They suggested that oxalate acts as a carrier for calcium in the absorption process and is subsequently reduced and condensed with coenzyme A to form malic acid However, some contradictory evidence has been presented by Osmond (1967) who found that in Atriplex (Australian salt bush) calcium absorption and oxalate synthesis varied independently, and that oxalate content was generally correlated with a high cation content as a whole rather than with the calcium alone

Since liming is a common practice in crop production, further studies on the effects of liming on oxalate content in plants should indicate if certain modification in this practice needs to be made to obtain a desirable crop quality with regard to oxalate content

Smith (1972) showed that a positive correlation exists between potassium applied and oxalate level in the grass Setaria sphacelata Moreover, significant relationships between oxalic acid and cation excess values were shown suggesting that accumulation of oxalic acid was the result of high application rates of potassium which in turn affected the cation excess

Soil pH affects the level of oxalic acid Wadleigh and Shive (1939) found that the total organic acid content, including oxalic acid, increased in corn plants as substrate pH was increased

Nitrogen in various forms exert profound effects on oxalate contents in plants The forms of nitrogen fertilizers investigated were mainly ammonium and nitrate (e g , Kirkby, 1968, Kirkby and Knight, 1977), and in some investigations, urea (e g Kirkby and Mengel 1967 Vityakon 1979) Generally nitrate resulted in a higher oxalate content than ammonium This observation has been explained in terms of cation-anion balance In general, nitrate fertilizer results in higher cation excess than ammonium Therefore, one recommended method of reducing the oxalate content in plants is to stabilize ammoniacal fertilizers with a nitrification inhibitor

The effects of phosphorus and zinc fertilizers on oxalate contents of plants have been investigated by Peck et al (1980) In table beets, which is a well-known oxalate accumulator, there was a clear relationship between increasing rates of phosphorus application and reduced oxalate levels in blades, petioles, and roots These workers suggested that phosphorus application lowered oxalic acid by reducing cation concentrations and also by lowering cation excess Zinc fertilizer did not appear to have any significant effects on oxalic acid in table beets They discussed the implication of these results from a human nutrition point of view and speculated that phosphorus fertilization of table beets might result in more available calcium

2 3 3 Environmental factors

Research on environmental factors affecting plant chemical composition is sparse and sometimes contradictory Singh and Saxena (1972) stated that environmental factors, such as light intensity season and temperature influenced the synthesis of oxalic acid in plants Eheart and Massey (1962) conducted a greenhouse experiment to study the effects of environmental factors on the oxalate content of spinach and concluded that plant variety was the only factor that had any significant effect on oxalic acid content Light intensity soil moisture, and all interactions did not affect the oxalate content of spinach

Kitchen et al (1964b) found that high temperatures decreased oxalates in spinach leaves and postulated that at high temperatures more oxalic acid was used as a respiratory substrate Gnedkov (1963 as cited by Singh and Saxena, 1972) observed an increase in oxalic acid concentration in some succulent plants maintained in the dark at a low temperature

The effect of soil moisture on organic acid content in plants was clearly demonstrated in tomato fruits by Lee and Sayre (1946) Citric acid contents were lower in tomatoes grown on wet soils than on dry soils

2 3 4 Stage of growth or maturity

The literature presents contradictory conclusions on the effect of stage of growth or maturity on the level of oxalate in plants Kitchen and Burns (1965) observed that both total and soluble oxalates in spinach decreased with age However some other scientists reported increases in oxalic acid contents in spinach with the development of the plant (e g , De Vilmorin and Bilques, 1957 Doesburg and Sweede 1948 as cited by Kitchen and Burns, 1965) Der Marderosian et al (1980) demonstrated that oxalate levels in chard, spinach and amaranth tended to increase with plant age The same trend was also found by Singh and Saxena (1972) in the leaves of six leafy vegetables including amaranth (Amaranthus gangeticus L), bathua (Chenopodium album L) kharbathua (C murale L), purslane (Portulaca oleracea L) spinach (Spinacea olearacea L) and beet (Beta vulgaris L) Furthermore the fractions of soluble and insoluble oxalate increased in leaves and decreased in stems with amaranth age However, Kitchen and Burns (1965) reasoned that the discrepancy was due to a combination of growth stage and season

2 3 5 Plant genetics

Eheart and Massey (1962) reported significant varietal differences in the oxalate content of spinach even though the range in oxalate content of 12 varieties was only 10 30-11 38% on a dry weight basis Kitchen et al (1964a) related the oxalate contents of different spinach varieties according to leaf morphology Total oxalate content ranged from 5 42% on a dry weight basis in savoyed-leaf varieties to 9 81% on a dry weight basis in smooth-leaf varieties

Different varieties of the tropical grass, Setaria sphacelata also contain different levels of oxalate For example the Kazungula and Bua River cultivars have 5 0% and 4 1% total oxalate respectively on a dry weight basis (Jones et al 1970) Amaranth varieties exhibit differences in oxalate content as shown by Der Marderosian et al (1980) These varietal and species differences offer a basis for selection and breeding work to lower oxalate contents in food crops

2 4 Nitrate accumulation in vegetables and its effects on human and animal health

Many plant species accumulate nitrate if nitrate is supplied in excess of N requirement Nitrate levels in plants cannot be measurably reduced without reducing yields (Lorenz, 1978) Nitrate accumulates in plants when uptake rate exceeds reduction and assimilation rates Such plant nitrate represents a major source of nitrate-N in human diets (Mills et al , 1976) Vegetables such as beets (*Beta vulgaris* L), spinach (*Spinacea oleracea* L), broccoli, celery (*Apium graveolens*), lettuce (*Lactuca sativa* L), radishes (*Raphanus sativus* L), kale (*Brassica oleracea*) mustard greens (*Brassica juncea*) collard (*Brassica oleracea* var acephala) (Table 2 1) and *Amaranthus* species (Table 2 2) may accumulate large quantities of nitrate

Nitrate distribution is not uniform in the plant In general nitrate levels are highest in petioles and stems moderate in leaves and roots and very low in fruit and flowers (Maynard and Barker 1972 Lorenz, 1978)

Levels of nitrate and nitrate derivatives in foods should be considered in evaluating potential health hazards in foods and feeds Nitrate itself is non-toxic to man and animals being readily absorbed and excreted but its derivatives (i e nitrite and nitrosamine) are toxic

Table 2 1

Range of nitrate content of field-grown vegetables purchased in Columbia, Missouri

Crop	Nitrate-N (% dry weight)
Beans	0 04 - 0 25
Beets	0 09 - 0 84
Broccoli	0 01 - 0 09
Brussel sprouts	0 01 - 0 06
Cabbage	0 01 - 0 09
Carrots	0 00 - 0 30
Cauliflower	0 00 - 0 31
Celery	0 11 - 1 12
Corn	0 00 - 1 01
Cucumber	0 00 - 0 16
Endive	0 06 - 0 67
Lettuce	0 02 - 1 06
Parsnip	0 00 - 0 04
Peas	0 00 - 0 02
Radish	0 41 - 1 54
Spinach	0 07 - 0 66
Squash yellow	0 09 - 0 43
Tomato	0 00 - 0 11

Source Brown and Smith 1967 as cited by Lorenz 1978

Table 2 2

Nitrate-N contents of the leaves of some *Amaranthus* species

Species	Nitrate-N (% dry weight)
A blitum	0 21
A cruentus	0 74
A dubius	0 27
A gangeticus	0 36 - 0 90
A hypochondriacus	0 65

(after Der Marderosian et al , 1981)

Nitrate is reduced to nitrite in humans and animals in their gastrointestinal tract Vegetables represent a major source of nitrate in human diets Nitrate in some vegetables (e g , lettuce and spinach) has been reported to be converted to nitrite during storage (Gersons 1974)

Nitrite reacts with hemoglobin to form methemoglobin and causes impairment to oxygen transport (Methemoglobinemia) In humans when the methemoglobin concentration exceeds 70%, asphyxia occurs At lower levels the reaction is reversible Apparently the reaction of nitrite with hemoglobin is inconsequential in adults but it can be critical in infants (Committee on Nitrate Accumulation 1972 Wolff and Wasserman 1972) In cattle abortion was associated with a methemoglobin level of 40% (Wolff and Wasserman 1972)

Nitrosamines are toxic derivatives of nitrate and nitrite as well as of secondary and tertiary amines Nitrosamines may have carcinogenic teratogenic (impaired development of embryo foetus) and mutagenic (cause of chromosomal aberation and gene mutation) properties Nitrosamines occur in foodstuffs such as cooked bacon polluted air water, and tobacco plants (Committee on Nitrate Accumulation 1972) Nitrosamines precursors may be converted to nitrosamines in the stomachs of mammals (Deeb and Sloan, 1975)

Lorenz (1978) has reviewed various works concerning the potential toxic level of nitrate for humans Sollman (1957) has given 0 70 g of nitrate-N as a possible single lethal dose for humans This result agrees with that proposed by Brown and Smith (1967), who stated that an adult weighing 70 kg would need to ingest approximately 0 7 to 1 0 g of nitrate-N for a toxic dose Deeb and Sloan (1975) set the lethal dose at 18 to 68 mg nitrate-N kg^{-1} of body weight for adults The lethal dose for nitrite was 22 to 33 mg nitrite-N kg^{-1} The U S Public Health Service (1962) suggested limits and ranges of nitrate-N in food and vegetables are as follows (1) zero for squash and tomatoes for strained baby foods and 833 ppm nitrate for spinach (2) 50 ppm (0 005%) for asparagus (dry weight) and 3600 ppm (0 36%) for spinach (dry weight)

Toxic levels of nitrate for animals vary greatly and depending upon other factors Lorenz (1978) has reviewed this subject and it appears that a level of 0 20% nitrate-N on a dry weight basis is potentially dangerous in livestock The University of Missouri (1958) has suggested that hay with less than 0 08% nitrate-N is safe for cattle while levels above 0 21% may result in death They suggest that the nitrate-N intake for a cow should not exceed 12 g per day The minimum lethal dose of nitrate is about 15 g per 45 4 kg of animal weight Deeb and Sloan (1975) list levels of 75 to 140 mg nitrate-N kg^{-1} of body weight as the toxic level for cattle and slightly lower values for sheep

Sources of nitrate for animals include a wide range of pasture plants and green feeds (e g , barley, wheat, corn, sugar beet, sunflower, turnips, pigweed, thistle, lamb s quarter, bindweed, nightshade ragweed, certain algae, and sometimes alfalfa) Animal processed food, such as soybean meal and molasses from cane and sugar beets also contain nitrate Nitrate-accumulating plants become the source of nitrite for animals when the plant materials are bruised and acted upon by plant enzymes or bacteria Moreover, any nitrate-containing food or feed processed by bacterial fermentation may, at some stage, contain appreciable amounts of nitrite Thus, silage prepared with water high in nitrate, commonly contains some nitrite, especially in the early stages of fermentation (Committee on Nitrate Accumulation 1972)

2 5 Factors affecting nitrate accumulation in vegetables

Two opposing processes regulate nitrate accumulation by plants nitrate uptake and nitrate assimilation Any factors that exert influence on these processes will, in turn, affect nitrate accumulation Before nitrate can be assimilated it must first be reduced to nitrite then to ammonium The first enzyme which catalyzes this process is nitrate reductase

2 5 1 Nutrient supply

Available soil nitrogen is the most important factor in nitrate accumulation in plants (Maynard and Barker 1972) Nitrate in plants is derived primarily from soil organic matter, plant residues, manures and fertilizer nitrogen The amount, source, time method of application, and numerous environmental conditions govern the effects of N fertilizers on nitrate accumulation in vegetables (Maynard et al , 1976)

Increasing rates of N application increase the nitrate concentration of vegetables (e g , spinach [Barker et al , 1971], table beets [Peck et al , 1971] and many other vegetables [Lorenz, 1978])

Due to mineralization and nitrification, nitrate is the primary N form absorbed by most plants regardless of the type of N applied Therefore, within limits, as much nitrate may be accumulated from organic or ammoniacal fertilizers as from nitrate fertilizers if sufficient time is allowed for mineralization and nitrification to occur (Peck et al , 1971) Usually, however, nitrate accumulates less from ammoniacal and urea fertilizers than from nitrate sources (Barker et al 1971, Peck et al , 1971 Lorenz and Weir, 1974)

Nitrate concentration in plants is also affected by the timing of N application For example spinach and table beets (Barker et al 1971, Peck et al , 1971) accumulated more nitrate when they were exposed to the same quantity of nitrate fertilizer earlier and for longer periods (i e broadcast application as opposed to side-dressing one week before harvest)

The accompanying cation influences nitrate absorption and hence its accumulation by plants Ammonium ion suppressed nitrate absorption more than Ca, K Na, or Mg ions (Minotti et al , 1969) There is much evidence to show that increasing K supply increases nitrate accumulation (Barker 1962, Minotti et al , 1968) Solution culture studies have shown that K generally stimulates nitrate absorption with respect to the effects of other cations (Minotti et al , 1968, Tottingham et al , 1934) Potassium has also been found to be the most regular counterion for transport of nitrate ion from root to shoot (Locher and Brouwer 1964, 1965, Louwerse and Alberda, 1965, Minotti et al , 1968)

Phosphorus supply does not have a strong effect on nitrate accumulation by vegetables Cantliffe (1973) did not find any influence of fertilizer P on nitrate concentration in spinach and table beets Brown and Smith (1967) in their field study on 30 species of vegetables showed that low P levels had little effect on nitrate levels in plants On the other hand Baker and Tucker (1971) reported that the addition of P reduced the amount of nitrate-N in wheat

2 5 2 Genetic factor

Nitrate accumulation is a function of variety in spinach (Barker et al , 1974), and lettuce (Maynard et al , 1976) Savoyed-leaf spinach varieties tend to accumulate more nitrate than smooth-leaf varieties, and semi-savoyed leaf types fall between them (Barker et al 1974) Differences in nitrate accumulation may be related to differences in uptake, assimilation or translocation Olday et al (1976) observed that nitrate reductase activity in smooth-leaf spinach was higher than in savoyed-leaf types It appears that differential assimilation is the primary cause for the observed differences in spinach varieties

The lettuce variety that accumulated least took up N most (Maynard et al , 1976)

Maynard et al (1976) suggested that the ratio of nitrate-N to total N could be taken as an indirect measure of assimilatory capacity This ratio varied greatly among varieties

2 5 3 Environmental factors

Environmental factors which affect nitrate accumulation in plants include light intensity, photoperiod and light duration water relation, and temperature

Cantliffe (1972b and 1972c) observed that increased nitrate reductase activity associated with high light intensity and long light duration decreased nitrate accumulation in spinach and other vegetables The need for light to activate nitrate reductase results in a diurnal fluctuation in nitrate concentration More recent work on spinach by Steingrover et al (1982) on spinach gave similar results A low-light' treatment, where plants were exposed to low light intensity throughout the night as opposed to normal darkness, seemed to affect nitrate reduction rather than nitrate uptake and transport Nitrate reductase activity in the leaf blades of the low light treated plants was about twice that in the dark-treated' plants It was suggested that a low-light' treatment one night before the harvest may provide a way to lower the nitrate content of commercially grown vegetables

Shading increased nitrate-N content in tall fescue (*Festuca arundinacea* Schreb) a nitrate accumulating forage crop (Stritzke et al 1976) Death of cattle grazing on tall fescue was attributed to nitrate poisoning This study showed that 30% shade and high N fertility increased the nitrate-N content of tall fescue significantly over those that received less shade and lower N

Moisture stress leads to excessive nitrate accumulation in forage (Wright and Davison, 1964) Water stress affects general assimilatory processes in plants and reduces nitrate reductase activity (Huffaker et al 1970), so that nitrate assimilation is depressed A more recent study by Leclerc and Robin (1983) showed that if soil water content of his test sample was near or below 2% marram grass (Ammophila arenaria L) diminished its assimilation activity and stored nitrate Above 2% soil water content, the nitrate reductase activity increased and the endogenous nitrate was consumed Several other processes in soils and plants that are moisture-dependent such as microbial activity movement of N to absorbing roots and transport in the xylem appear to increase nitrate levels in plants (Wright and Davison, 1964)

Maynard et al (1976) speculated on the possible effects of humidity and, thus transpiration, on nitrate accumulation They postulated that reduced humidity and increased transpiration rates were involved in maintaining a continuous movement of nitrate to reduction sites, thereby helping to maintain nitrate reductase and keeping accumulated nitrate low The authors postulated that high humidity might enhance nitrate accumulation and suggested that the higher nitrate in glasshouse plants relative to plastic-house plants (10% lower light intensity in plastic house) might not be due to the light intensity effect but rather to the higher humidity in glasshouses

There is considerable evidence to show that high temperatures increase nitrate content in various plants such as barley (Hordeum vulgare L) (Onwueme et al 1971) lettuce (Frota and Tucker, 1972) corn (Zea mays L) (Mattas and Pauli, 1965), pasture plants (Bathurst and Mitchell, 1958), and spinach (Cantliffe, 1972a) Cantliffe (1972a) attributed this effect to deactivation of nitrate reductase and also to higher soil availability of nitrate resulting from increased microbial activity at high temperatures

According to Maynard et al (1976) a general statement about the effects of temperature on nitrate accumulation should not be made, because N absorption, translocation and assimilation are all affected by temperature The relative degree to which each process was affected depended on other factors Factors such as light, moisture, and N availability are important which could in turn be markedly affected by temperature They cited examples of the effects of the interactions of two factors on N accumulation Cantliffe (1972a) noted that nitrate accumulation in spinach was affected by the interaction of temperature and amount of N applied At zero fertilizer N, nitrate accumulation did not begin until temperature was greater than 15^{o}C, but at 50^{o} and 200 mgN kg^{-1} soil, nitrate accumulation began at 10^{o}C and 5^{o}C respectively Hoff and Wilcox (1970) reported effects of temperature and light interaction on nitrate accumulation in tomatoes (Lycopersicon esculentum Mill) They found that temperature exerted its greatest effect (highest nitrate accumulation) at high N and low light and that light exerted its greatest effect at high temperature and high N

2 6 Relationship between total N and nitrate-N concentrations in plants

Terman et al (1976) have shown that total N and nitrate-N concentrations in plants are related In pot and nutrient solution experiments, nitrate-N accumulation by corn commenced when total N exceeded 2 5% in the leaves and 1 5% in the stems In spinach and mustard nitrate-N concentration increased rapidly when total N exceeded 4 0% but approached zero below 4 0% Nitrate-N in fescue grass was less than 0 1% up to 3% of total N and beyond that increased linearly with total N The workers concluded from these studies that

1 The occurrence of high levels of total and nitrate-N during early growth depended on the abundance of available soil and fertilizer N

2 As plant growth continued, total and nitrate-N decreased as a result of dilution and assimilation Such decreases occurred with age and in response to P, K and other factors

3 As total N decreased all forms of unassimilated N were depleted

4 Except during the early growth stage high nitrate-N concentrations in plants are usually the result of diminished growth due to unfavorable conditions such as drought, low or high air temperatures, poor light together with continued uptake of nitrate-N

5 If the rate of plant growth was higher than that of N absorption much of the nitrate would be incorporated into proteins However, low concentrations of nitrate-N ($< 0\ 05\%$) can remain in conductive tissues

2 7 Chemistry of oxalate with an emphasis on its biosynthesis in plants

Franceschi and Horner (1980) have reviewed studies on the synthesis of oxalic acid in high oxalate plants such as rhubarb buckwheat *Begonia* *Oxalis*, *Atriplex* *Setaria* spinach and beetroot According to Raven et al (1982) there are four major pathways of oxalate biosynthesis Interestingly, all four pathways have been suggested for spinach The four pathways are shown in Figure 2 1 and include

1 Formation of glyoxylate from glycollate by the action of glycollate oxidase, followed by oxidation of the glyoxylate to oxalate by action of the same enzyme

2 Formation of glyoxylate from isocitrate by the action of isocitrate lyase, followed by oxidation of glyoxylate to oxalate

3 Formation of oxalate from oxaloacetate by the action of oxaloacetate lyase

4 Formation of oxalate from C_1 and C_2 of L-ascorbate

The first 2 mechanisms have glyoxylate as the immediate precursor of oxalate Glyoxylate is oxidized to produced oxalate (reaction)

$$\underset{\text{glyoxylate}}{\begin{array}{l}\text{CHO}\\ |\\ \text{COOH}\end{array}} \longrightarrow \underset{\text{oxalate}}{\begin{array}{l}\text{COOH}\\ |\\ \text{COOH}\end{array}} \qquad (1)$$

Mechanism 1 appears to have some connection with photosynthesis or more precisely, photorespiration The conversion of glyoxylate to oxalate occurs in green tissue and is facilitated by light (Sengupta and Sen 1976) Both photorespiration and oxalate synthesis via mechanism 1 use the same substrate glycollate with subsequent formation of glyoxylate

Mechanism 2 is contrastingly different from mechanism 1 because oxalate is synthesized in the dark β-carboxylation of phosphoenol pyruvate (PEP) provides the basis of a non-crassulacean acid metabolism common in plant tissue This process is also called dark CO_2 fixation

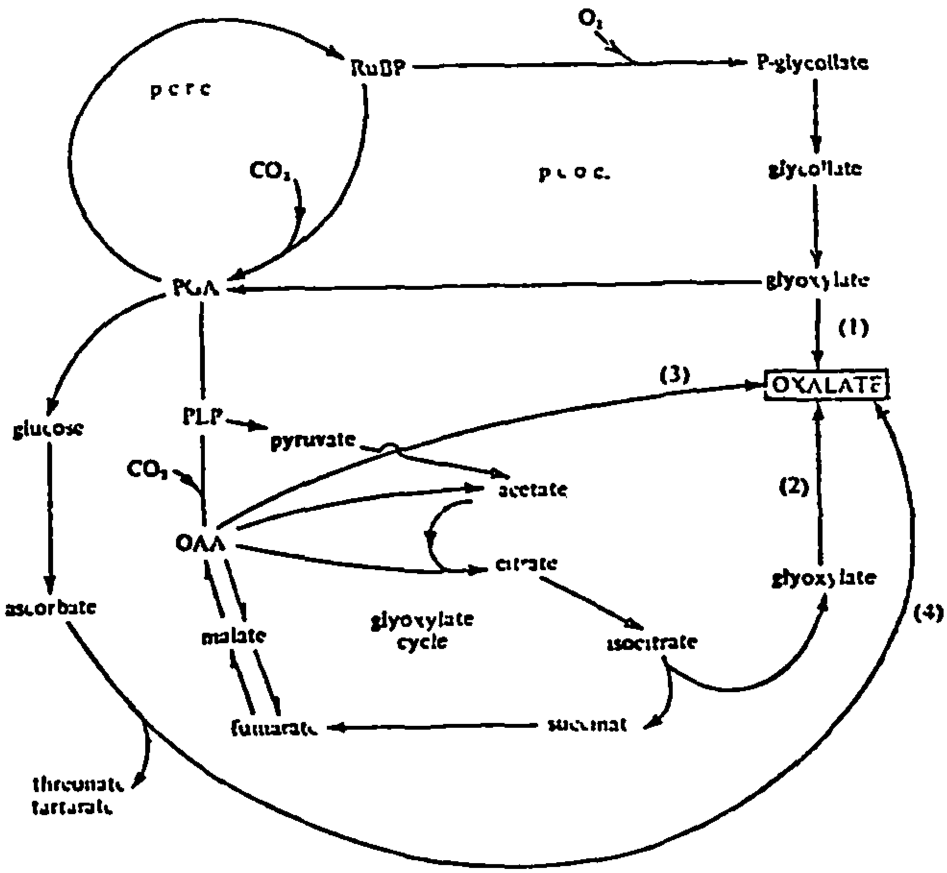


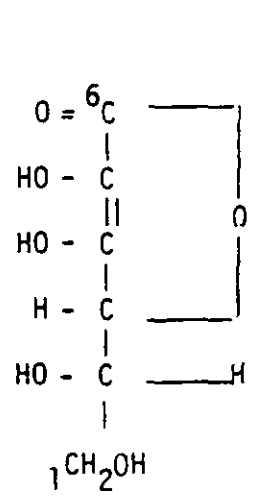
Figure 2 1 The four proposed pathways to oxalate (1) from phosphoglycolate generated in the RuBPo reaction (2) from glyoxylate produced in the isocitrate lyase reaction, (3) from oxaloacetate via oxaloacetate lyase (4) from ascorbate by oxidation
OAA = Oxaloacetic acid, p c o c = photosynthetic carbon oxidation cycle, p c r c = photosynthetic carbon reduction cycle PEP = phosphoenol pyruvate PGA = 3-phosphoglycerate P-glycollate = phosphoglycollate

(Source Raven et al 1982)

because it does not require light The products of this CO_2 fixation are C_4 compounds which can enter the tricarboxylic acid (TCA) cycle to be metabolized with subsequent energy generation According to Osmond and Avadhani (1968) oxalate is not an early product of carboxylation reactions but is synthesized from intermediates of subsequent TCA cycle metabolism The TCA cycle intermediate that is a likely oxalate precursor is isocitrate which gives rise to glyoxylate by the action of isocitrate lyase

Mechanisms 3 and 4 do not have glyoxylate as the substrate for oxalate Chang and Beevers (1968), who discovered mechanism 3 indicated that oxalate was produced as a by-product of acetate utilization in the TCA cycle Oxalate synthesis involves the cleavage of C_4 oxaloacetate to yield acetate and oxalate The enzyme which catalyzes this reaction is oxaloacetate lyase

Mechanism 4 uses L-ascorbic acid as a precursor of oxalic acid This mechanism has been found in many oxalate accumulating plants, such as _Rumex crispus_ L (curly dock), _Amaranthus retroflexus_ L (red root pigweed), _Chenopodium album_ L (Lamb s quarters) _Beta vulgaris_ L (sugar beet), _Halogeton glomeratus_ M Bieb (halogeton) and _Rheum rhabarbarum_ L (rhubarb) (Nuss and Loewus, 1978), and also in species with low oxalate content such as barley (Wagner 1981) It was found by labelling studies that C_1 and C_2 fragments of ascorbic acid give rise to the carbons in oxalic acid (refer to the structure of the acid below) (Nuss and Loewus, 1978) More biochemical work needs to be done to establish the enzymic basis of this conversion and to determine the site of the activity



L-ascorbic acid

Recent work on the subject of oxalate biosynthesis by Raven et al (1982) uses non-radioactive isotopes, $^{18}O_2$, ^{12}C, and ^{13}C, to investigate the relative significance of the four mechanisms of oxalate biosynthesis Their results indicate that the role of mechanism 1 is not important for oxalate synthesis in spinach This mechanism is the only one that requires light or in other words, is the only one that occurs in green tissue Earlier work has shown that organic acid or carboxylate synthesis is connected to dark CO_2 fixation (e g Osmond and Avadhani 1968 Chang and Beevers 1968)

2 8 Relation between oxalate synthesis nitrate accumulation and nitrogen metabolism in plants

There are connections between oxalate synthesis nitrate accumulation, and nitrogen metabolism in plants As mentioned in section 2 5 nitrate accumulation depends upon the rate of nitrate uptake and the rate of nitrate assimilation Nitrates accumulate in plant tissue when the rate of nitrate assimilation ceases or is slow Nitrate enters the protein metabolism pathway after it is reduced to ammonia The connection between protein metabolism and carboxylate (organic acid) synthesis will be described

Studies on nitrate and oxalate accumulations on different spinach varieties have shown that there is a relationship between leaf type and nitrate and oxalate accumulations Savoyed-leaf spinach cultivars tend to accumulate the most nitrate while smooth-leaf spinach are able to maintain low nitrate concentrations The semi-savoyed leaf type behave in an intermediate manner (Barker et al , 1974, Maynard and Barker, 1974) On the other hand Kitchen et al (1964a) found the savoyed-leaf types to have the lowest oxalate content and smooth and semi-savoyed leaf types to have the highest content While this can be taken as evidence of the connections between nitrate accumulation, N metabolism and oxalate accumulation, it is not a direct one

Studies on the role of carboxylic acids in nitrogen metabolism up to the mid 1960s were reviewed by Beevers et al (1966) The effects of ammonium and nitrate ions on organic acid contents have been observed in various plants (Beevers et al , 1966, p 231) The acid content increases in plants treated with ammonium or nitrate nitrogen relative to the untreated ones, and the increase is greater in nitrate-fed plants than ammonium-fed plants (Beevers et al , 1966, Kirkby and Mengel, 1967 Kirkby, 1969 Kirkby and Knight 1977, Vityakon 1979) Similar response to ammonium and nitrate has been found in oxalate accumulating plants such as spinach and beetroot (Vityakon 1979)

According to Beevers et al (1966) ammonium and nitrate utilization impinged directly upon the metabolism of carboxylic acids Work in the 1970s and 1980s has used isotopically labelled CO_2 to examine the effects of ammonium and nitrate nutrition on dark CO_2 fixation Ikeda and Yamada (1981) investigated the effect of ammonium and nitrate nitrogen on dark CO_2 fixation in tomato leaves Dark CO_2 fixation involves the enzyme phosphoenol pyruvate carboxylase which catalyses the following reaction

PEP	+	CO_2	$\longrightarrow$	OAA	+	P_i	(2)
phosphoenol pyruvate				oxaloacetate		inorganic P	

Ammonium-fed plants were remarkably less able to fix $^{14}CO_2$ in the dark compared with nitrate-fed plants Furthermore, the phosphoenol pyruvate carboxylase activity of ammonium-fed plants was lower than that of nitrate-fed plants Fixed $^{14}CO_2$ was more rapidly utilized for amino acid synthesis in ammonium-fed plants than in nitrate-fed plants

More than 50% of total organic acids in tomato consist of malic acid Not only is malic acid synthesized through the TCA cycle in mitochondria but it is also produced by the carboxylation of C_3 compounds catalyzed by soluble enzymes in the cytoplasm (i e oxaloacetate produced in reaction 2 can be metabolized to malate by the enzyme malate dehydrogenase) Inference can also be made concerning the synthesis of oxalate from the oxaloacetate precursor produced in reaction 2 along the pathway of mechanism 2 or 3

Hammel et al (1979) investigated the effect of ammonium on carbon metabolism in isolated mesophyll cells of Papaver somniferum L Ammonium chloride solution was used as the nitrogen source Addition of ammonium ion to isolated mesophyll cells resulted in an increase in the rate of dark ^{14}C fixation relative to that in untreated cells The most rapid increase in labelling the metabolite occurred in aspartate and was accompanied by a decrease in the level of labelled phosphoenol pyruvate This indicates that ammonium stimulates phosphoenol pyruvate carboxylation in this system

Possible effects of ammonium on glycolysis and respiratory metabolism were investigated by Hammel et al (1979) The level of labelled pyruvate did not change nor were there effects of ammonium on the pyruvate kinase reaction in the dark (reaction 3) Such results indicate that ammonium is not important to the reaction

$$\text{PEP} \xrightarrow{\text{pyruvate kinase}} \text{enol pyruvate} \longrightarrow \text{pyruvate} \quad (3)$$

However Ikeda et al (1974) showed that there was an enhancement of glucose degradation (glycolysis) and respiratory metabolism (TCA cycle) in the leaves of tomato plants supplied with high levels of ammonium nitrogen for seven consecutive days They suggested that the enhanced respiration in ammonium-fed plants is due to assimilation/detoxification of NH_4^+-N This reaction keeps the levels of NH_4^+ - N and organic acids low The organic acids are replenished mainly by intermediates in glycolysis and the TCA cycle

Paul et al (1978) reported the enhancement of both pyruvate kinase and phosphoenol pyruvate carboxylase in isolated mesophyll cells of *Papaver somniferum* L supplied with ammonium and light They concluded that the net effect of an addition of ammonia to mesophyll cells was a redistribution of newly fixed carbon away from carbohydrates and into amino acids

In a study of effect of ammonium on dark CO_2 fixation products of *Euglena* Peak and Peak (1980) measured an overall increase in glutamine and the amount of $^{14}CO_2$ fixed Both were heavily labelled Furthermore, they postulated with some supporting evidence that the labelled CO_2 entered the amino acids via the TCA cycle by way of the carboxylation of phosphoenol pyruvate

Peak and Peak (1980) reported that ammonium stimulation caused increased incorporation of labelled CO_2 into some amino acids not derived from TCA cycle intermediates including for example glycine serine, and alanine, which are all derived from the glycolytic pathway Since it is known that Euglena possesses the glyoxylate shunt enzymes isocitrate lyase and malate synthase, these researchers suggested that it should be feasible that CO_2 could enter glycine and serine via the TCA cycle intermediates, oxaloacetate and isocitrate, which are glyoxylate precursors

Although the studies presented so far do not directly relate nitrogen to oxalate synthesis, the connections of these nitrogen-related biochemical processes to oxalate metabolism can be seen The process of dark CO_2 fixation which involves the enzyme phosphoenol pyruvate carboxylase and the product oxaloacetate is a direct precursor of oxalate formation, also oxaloacetate can lead to the synthesis of isocitrate, which can lead to the synthesis of glyoxylate by the catalysis of isocitrate lyase Furthermore, these studies have thrown some light on the long-observed phenomenon of a relatively higher organic acid content (including oxalate) in nitrate-fed plants compared with ammonium-fed plants

2 9 The use of amaranth, cassava, and taro as vegetables

Amaranth, cassava, and taro have been consumed in the tropics since ancient times Amaranth was an important grain crop of the Aztecs and the Incas (National Research Council 1984) Taro is grown throughout the humid tropics for edible corms and leaves as well as for traditional ceremonial uses (Wang, 1983) Although widely used, the term 'under-exploited crop has been applied to amaranth and taro (National Academy of Science, 1975) because they are relatively unknown to the industrialized world In contrast, in the industrialized world key food crops have been bred to suit large scale monoculture farming systems with consequent high yields for economic purposes From this point of view, cassava is different from amaranth and taro Cassava is a well-known root crop, now grown on a large scale and is an important commodity in international trade Much research work has been done on cassava, for example at the Centro Internacional de Agricultura Tropical (CIAT) in Columbia The use of cassava leaves is relatively unknown although they are rich in protein

2 9 1 Distributions of the crops and their uses

Amaranth seeds and leaves are used for human consumption Principal uses and areas of origin of many *Amaranthus* species are summarized in Table 2 3 Amaranth grows in many regions of the world As far as the edible vegetative parts (i e , leaves and young shoots) are concerned *Amaranthus* species such as *A tricolor* *A dubius* and *A cruentus* are grown for their value as soup vegetables or for boiled salad greens particularly in the hot, humid regions of Africa Southeast Asia (especially Malaysia and Indonesia) southern China southern

Table 2 3

Uses and areas of origin of *Amaranthus* species (after Teutonico and Knorr, 1985)

Species	How found	Use	Area of origin
A blitum (*A lividus*, *A oleraceus*)	Cultivated	Vegetable, ornamental	Asia
A caudatus *A edulis* (*A mategazzianus*)	Cultivated	Grain vegetable, ornamental	South America (Andes)
A cruentus (*A paniculatus*)	Cultivated	Grain, vegetable	South America (Guatemala)
A dubius	Weed, cultivated	Vegetable	South America
A hybridus	Weed	Vegetable	South America
A hypochondriacus (*A leucocarpus*, *A leucosperma*, *A flavus*)	Cultivated	Grain, vegetable	North America (Mexico)
A retroflexus	Weed	Vegetable	North America
A spinosus	Weed	Vegetable	Asia
A tricolor (*A gangeticus*, *A mangostanus*)	Cultivated	Vegetable	Asia
A viridis (*A ascendens*, *A gracilis*)	Weed	Vegetable	Africa

India, and the Caribbean *A palmeri* is a major wild green for the Indians in the North American deserts, and *A blitum* leaves have been a favorite salad in Greece since ancient times (National Research Council, 1984) *Amaranthus* species along with other wild plants are used by the Tanzanians as relishes that are an integral and essential part of the diet in all seasons of the year (Fleuret, 1979)

Taro (*Colocasia esculenta* (L) Schott) is a member of the Araceae family Primarily it is a root crop but leaves are also consumed extensively in Africa, Asia, the West Indies, and South America However, taro consumption is greatest in the Caribbean, Hawaii the Solomon Islands, American Samoa, Western Samoa, the Philippines, Fiji, Sri Lanka, India, Nigeria, Indonesia, New Hebrides, Tonga, Niue, Papua New Guinea, and Egypt Young taro leaves are an important vegetable throughout Melanesia and Polynesia (Wang, 1983)

Cassava (*Manihot esculenta* L) is one of the most important root crops of the world The root is the fourth most important energy staple of the tropics, providing food and income for 750 million people in three continents of Africa, Asia and America

The consumption of cassava leaves as a vegetable is widespread among the native peoples of many Asian countries such as Malaysia, Indonesia, and Thailand The cyanide content of cassava leaves precludes their use as a vegetable in Nigeria (Oke, 1968)

2 9 2 Nutritional values and some limitations

Considerable work has been done in India on evaluating the nutritional value of amaranth Many species of amaranth are used as greens in India and their nutritional value to low income groups is well known

According to Rao et al (1980), amaranth is considered the king of vegetables with regard to its nutritional value and its low price Like many other green leafy vegetables in India, amaranth is 'within reach of the poor man' Much of the research has been focused on the use of amaranth as a food supplement For example, Devadas et al (1964) investigated the use of amaranth and other green leafy vegetables as supplements for rice-based diets They found that amaranth and vegetable supplements improved the calcium status of the body as indicated by a positive calcium balance and higher calcium levels in the bones of experimental albino rats In addition, the overall growth of animals on a diet that included amaranth was improved

Amaranth, like other green leafy vegetables, is an important source of vitamins A and C, which are of considerable nutritional significance (Table 2 4) (National Research Council, 1984, Teutonico and Knorr, 1985) In places like Kenya amaranth also provides a cheap source of vitamin C relative to more expensive sources like citrus (Abe and Imbamba, 1977)

With regard to minerals, amaranth has high iron and calcium contents relative to other greens such as spinach, Malabar spinach (Basella) and chard (National Research Council, 1984) Guttikar et al (1966) also reported that amaranth greens (A tricolor) was a very rich source of magnesium when compared with other Indian foodstuffs including pulses, leafy vegetables, other vegetables and fruits Data reported by Teutonico and Knorr (1985) confirm that amaranth contains potassium, iron, magnesium and calcium in significant concentrations (Table 2 4)

Protein is another important nutrient of amaranth greens Its leaf can be used in the wet tropics to ameliorate protein shortages (Pirie

Table 2 4

Composition of vegetable amaranth

Analysis	Content									
	A cruentus	A edulis	A hypochondriacus	A retroflexus	A tricolor	A caudatus	A spinosus	A viridis	A graecizans	A hybridus
Moisture					85 7	70 1 90 9	79 0 83 0	94 0	84 0	
Crude protein (%N x 6 25 dm)	20 9 33 0	18 0	21 6	21 1 21 2	32 7	17 4 29 7	28 4 31 0	38 3	23 2	22 1 33 5
Total lipids[a]	1 58 6 7	1 60	1 96	1 58	3 5 10 6	1 0 2 8	1 8 4 5	1 7	1 7 3 2	1 3 6 5
Crude fiber[a]	8 6 13 1	12 4	11 8	13 1 13 5	7 0	5 4 9 2	9 4	13 3	14 5	10 5 24 6
Crude ash[a]	16 1 21 6	22 0	21 2	20 4 22 2		19 3 21 0	22 1		21 7	7 6 19 0
Na[a]						0 01 0 04	0 01		0 01	
K[a]	2 9 6 1	3 7	5 6	5 4 5 6		0 3 5 0	0 3		0 2	
Ca[a]	1 9 2 6	6 2	2 6	3 0	3 5	2 3 2 6	1 1 1 8	2 3	1 8	3 3
Mg[a]	1 1 2 2	2 2	1 2	1 4 1 7	1 7	1 1 1 3	2 2		1 5	
Fe[a]	0 02 0 04	0 02	0 02	0 04 0 05		0 02	0 01	0 008		0 00
Zn[a]	0 05	0 002	0 004	0 005 0 008						
P[b]	0 4	0 3	0 5	0 3 0 5	0 7	0 3 0 4	0 4			
Riboflavin[b]					2 1					
Niacin					8 4(0 8[c])	4 7	7 7		6 2	
Ascorbic acid[c]					693(55[c])	210	250	147		30 48[c]
Thiamin[c]					0 02					
carotene (IU/100 g dm)					23 000 (1 710[d])	25 400	54 110	48 000		

a % dry matter b mg/ 100 g dry matter c mg/ 100 g fresh weight d g/ 100 fresh weight

Source Teutonico and Knorr 1985

1966) Leaves of this and other specific tropical plants contain protein of high quality (Akeson and Stahmann, 1965 Gerloff et al , 1965 as cited by Madamba, 1972) Attempts to promote the use of leaf protein have been underway for some time in the tropics In Nigeria the traditional corn grinding mill was used to extract leaf protein from vegetables such as Amaranthus caudatus (Olatunbosun, 1976) Adding approximately 10 g of leaf protein a day to the low protein diet of children suffering from protein-calorie malnutrition resulted in significant clinical improvement

Research on the production of protein concentrate from amaranth leaves (e g , Carlsson, 1980 in Sweden, Cheeke et al , 1981) has been designed to make proteins in green plants available to non-ruminants because leaf protein concentrate no longer has the cellulose and fiber that is indigestable to non-ruminants Amaranthus species contain large amounts of extractable protein (Lexander et al , 1970), but protein concentrates from amaranth have not improved growth of experimental rats Cheeke et al (1981) postulated that poor growth may be associated with a high ash content and organic substances such as saponins phenolics and oxalates These factors need to be overcome before amaranth or its protein concentrate can be utilized successfully

The lysine content of amaranth is high This amino acid is frequently deficient in cereal-based diets (Oliveira and de Carvalko 1975, Kamath and Sahonie, 1959) Oliveira and de Carvalko (1975) reported that in Mozambique, A spinosus leaves had lysine contents as high as 5 2% The benefit of supplementing a maize meal with A spinosus was evidenced by the fact that the chemical score of the mixture was raised to 43, compared to 28 for maize meal alone and 32 for amaranth leaves alone

The National Research Council (1984) has reported leaf-protein levels (on a dry weight basis) as follows 27% for A blitum, 28% for A hybridus, 30% for A caudatus, 32% for A gracilis, 23% for A graecians and 28% for A spinosus The range of protein content in various species of amaranth is presented in Table 2 4

Taro leaves

Young leaves and petioles of taro are used as vegetables They are useful sources of vitamin A and vitamin C (Table 2 5) Taro leaves are used extensively for cooking in Pacific islands such as Hawaii Fiji, Samoa and Tonga Taro leaves are also rich in mineral calcium and potassium (Table 2 5) (Standal, 1983) Crude protein contents are comparable to those of amaranth and cassava as shown in Table 2 5

Cassava leaves

Cassava leaves are rich in protein, carotenes, vitamins B_1, B_2 and C, and minerals (Oke, 1968) Rogers and Milner (1963) reported that the protein content of cassava leaves ranged from 17 8 to 34 8% on a dry weight basis for Brazlilian varieties and from 18 5 to 32 4 for Jamaican varieties Concentrations of essential amino acids are adequate except for methionine (Eggum, 1970 Rogers and Milner 1963) Adding methionine to a diet of cassava leaves raised the biological value from 49 for the leaves alone to 80 for the mixture (Eggum 1970) Rogers and Milner (1963) considered the composition of essential amino acid of cassava leaf protein to be similar to that of soybean which is one of the best in nutritive value among the readily available

Table 2 5

Nutrient composition of taro leaves

Composition per 100 g of fresh wt	India	Philippines	Hawaii
Edible portion (%)	-	55 0	-
Moisture (g)	78 8	79 6	88 0
Protein (g $100g^{-1}$ dry wt)	32 1	21 6	22 7
Fat (g)	2 0	1 8	0 7
Carbohydrates (g)	8 1	12 1	4 8
Fiber (g)	1 8	3 4	2 0
Food energy (kcal)	77 0	69 0	36 0
Ash (g)	-	2 0	2 0
Calcium (mg)	460 0	268 0	107 0
Phosphorus (mg)	125 0	78 0	60 0
Iron (mg)	38 7	4 3	2 3
Sodium (mg)	-	11 0	2 0
Potassium (mg)	-	1237 0	437 0
Vit A value (IU)*	2000	20385 0	5028 0
Thiamine (mg)	0 1	0 1	0 14
Riboflavin (mg)	0 5	0 33	0 31
Niacin (mg)	1 9	2 0	1 0
Ascorbic acid (mg)	63 0	142 0	37 0

* 0 6 ug = 1 IU

Source Standal, 1983

vegetable proteins The use of cassava leaf for producing protein concentrates is being investigated by several food scientists (e g Luiza et al , 1979)

The vitamin A content of cassava leaves is as high as 0 5 unit g^{-1} Various sources report vitamin C content ranging from 29 to 180 cmol kg^{-1} in cassava leaves (Oke, 1968)

Limitations

Amaranth, taro, and cassava leaves contain oxalate and accumulate a certain amount of nitrate The presence of an antinutrient and toxic agent lowers the nutritive value of these vegetables, as discussed in section 2 2

2 10 Estimation of oxalate contents

Two techniques of oxalate quantification are to be discussed The first, termed the 'classical method' was developed through a series of improvements of existing techniques before the 1950s Papers by Baker (1952) and Moir (1953) are frequently cited by researchers who use the 'classical method in their work The Association of Official Analytical Chemists (AOAC) has certified this technique for total oxalate determination (Horwitz, 1975)

The classical method of oxalate determination has three steps

1 Separation of oxalate by means of calcium oxalate precipitation at pH 4-5,

2 Determination of calcium by titrimetric or spectrophotometric methods,

3 Calculation of oxalate equivalents from calcium analysis (Baker, 1952 Moir, 1953 Horwitz 1975)

One difference between the methods employed by Baker (1952) and Moir (1953) is that Baker used fresh plant material to avoid loss of oxalate from drying whereas Moir used dried ($100^{o}C$), plant material

Baker (1952) proved the effectiveness of this technique by demonstrating 99-100% recovery of added oxalate

The second technique is based on the use of high performance liquid chromatography (HPLC) developed in the 1970s In HPLC a mobile phase is allowed to percolate through the stationary phase packed in a column continuously and the sample in the same solvent as the mobile phase can be injected into the mobile phase as desired

A paper describing the effectiveness of the HPLC technique for determining oxalic acid and comparing this technique with the classical method has been published (Libert, 1981) Libert used a reversed-phase column called the Lichrosorb RP-8 (C_8) as the stationary phase and a solution containing 0 5% KH_2PO_4 and 0 05 M tetrabutyl ammonium hydrogen sulphate (TBA), buffered at pH 2 with orthophosphoric acid, as the mobile phase One advantage of HPLC is the simultaneous determination of organic acids other than oxalic acid The determination of oxalic acid levels in rhubarb by the HPLC technique has been shown to give comparable results to the classical method

CHAPTER III

MATERIALS AND METHODS

In order to test the hypothesis that the variance in the nutritional quality of food crops is strongly influenced by cultural and environmental factors, the following experimental sites crops, experimental design and data collection and analysis procedures were selected

3 1 The experimental sites

Four experimental sites were selected to represent a range of agroenvironments These sites were developed by the Benchmark Soils Project (BSP) of the University of Hawaii to test the hypothesis that agroproduction technology can be successfully transferred from one location to other distant sites around the world provided the biophysical environment of the site where the technology was developed was similar to the transfer site The project defined similar environments according to the criteria set forth to define the soil family in Soil Taxonomy (Soil Survey Staff, 1975) Soil Taxonomy is a comprehensive system of soil classification for making and interpreting soil surveys issued by the Soil Conservation Service of the U S Department of Agriculture

By 1980, the project had established experimental sites in the Cameroons in Africa, Brazil Puerto Rico the Philippines Indonesia and Hawaii Three soil families were selected to test the hypothesis that similar agroproduction technologies and management practice would result in similar crop performances and yields among soils belonging to the same soil family regardless of where they occurred The three soil families selected were the clayey, kaolinitic isohyperthermic family of the Tropeptic Eutrustox, the thixotropic isothermic family of Hydric Dystrandepts and the clayey, kaolinitic, isohyperthermic family of Typic Paleudults

The Tropeptic Eutrustox are found in the warm semi-arid tropics and are nutrient-rich Oxisols Experimental sites with this soil were established in Puerto Rico, Brazil and Hawaii In Hawaii the experimental sites were established in Waipio on the Island of Oahu and on the west end of the Island of Molokai

The Hydric Dystrandepts are impoverished soils that have formed from volcanic ash and are well known for their low phosphorus levels The isothermic members of Hydric Dystrandepts occur in the cool tropics and the mean annual temperature is between 15 and 22^{o}C Experimental sites with soils of this family were established in the Philippines, Indonesia and Hawaii In Hawaii, the sites were established on the Big Island of Hawaii at Iole and Niulii on the upper slopes of the Kohala Mountains and at Kukaiau on the slope of Mauna Kea

Experimental sites for the Typic Paleudults were established in Cameroon, Indonesia and the Philippines These soils are highly acid nutrient-poor and occur in the warm humid tropics No experimental site of this soil was established in Hawaii

Each experimental site was carefully characterized for soil and provided with a weather station that recorded wind speed and direction relative humidity, solar radiation maximum and minimum air temperature topsoil and subsoil temperatures and rainfall The results of this project are summarized in a book entitled Soil-Based Agrotechnology Transfer' (Silva 1985)

In 1982 a workshop on A Multidisciplinary Approach to Agrotechnology Transfer (1984) was held at the University of Hawaii At this workshop, the nutritionists reminded the agronomists that the objective of agriculture research was not simply to increase yield but to provide adequate nutrients for people

In a paper on the 'Relationship of Soil Composition to the Nutrient and Antinutrient Contents of Plants" presented at that workshop, Van Reen (1984) suggested that the data in food composition tables were not very reliable because there is evidence that the composition of the same edible plant grown in different parts of the world is very different (Food and Agriculture Organization 1954)

In the same paper Van Reen listed factors that may contribute to variations in food compositions These are

1 Genetics of the variety of the plant
2 Light intensity and duration (season)
3 Temperature condition
4 Water conditions
5 Soil types
6 Type and amount of pesticide/herbicide
7 Type and amount of fertilizers
8 Age of plant material
9 Part of the sample analyzed

It was evident from Van Reen s paper that the Benchmark research sites established by the Benchmark Soils Project were ideally suited to assess a number of the factors which could influence variation in nutrient contents

It was decided to select four Benchmark research sites to test the hypothesis that nutrient composition in general and antinutrient content in particular vary with genotype and environment These sites were the Waipio site on the Island of Oahu the Molokai site on the west end of the Island of Molokai the Iole site in the Kohala district of the Island of Hawaii and the Kukaiau site in the Hamakua District also on the Island of Hawaii Tables 3 1, 3 2 and 3 3 summarize the characteristics of each site

3 2 Crops

Three crops were selected on the basis of their availability for growing and/or obtaining samples and their relevance to the nutritional quality of interest, namely the contents of oxalates and some mineral nutrients These crops were amaranth (*Amaranthus gangeticus* L), cassava (*Manihot esculenta* L) and taro (*Colocasia esculenta* (L) Schott) These crops, with the exception of amaranth were part of the existing cropping systems experiments of the Benchmark Soils Project They were known to have high oxalate contents

Amaranth belongs to the family Amaranthaceae It is commercially known in the United States as tampala In Hawaii, it is also known as Hinn Choi or Chinese spinach It is a spinach-like vegetable with dark green leaves which are elongated and smooth (Cole 1979) The plants are succulent, low growing and compact with growth habit much like spinach (National Research Council 1984) Under optimum conditions, the plants reach their harvestable size in 45 days after seed sowing The leaves and young tender stem are eaten as greens *A gangeticus* L has been proved to be the same species as *A tricolor* L

Table 3 1

Description of geographical positions[a] and history of soil use[b] of the experimental sites

Sites	Geographical position and history of soil use
Kukaiau	This site is situated on the Island of Hawaii, approximately 2 5 km southeast of the town of Honokaa and approximately 0 6 km from a plantation road southeast of the junction of highways 19 and 24 and 0 3 km southeast of an abandoned church The elevation is approximately 395 m and the slope is moderate to strong (6 percent slope, north aspect)
	The soil was formerly grown to sugarcane In 1976, it was planted to soybean and in 1977 to corn It was then fallowed until 1982 when cropping systems experiments were begun in which the fertilizers (lime epsom salt, borax and zinc sulfate), in quantities as shown in Table 3 4 were applied yearly The soil on this site is a member of the thixotropic, isothermic family of Hydric Dystrandepts
Iole	This site is situated in North Kohala, Island of Hawaii, approximately 5 6 km south southeast of the town of Hawi, approximately 7 2 km southwest of Kapaau village The elevation is approximately 545 m and the site occurs on moderately sloping to strongly sloping (6 percent slope north aspect) land
	The soil was formerly planted to sugarcane Maize experiments in which different rates of N and P were applied, were conducted in 1977 It was left fallow after the maize experiments until 1982 when cropping systems experiments were started, and fertilizers (lime epsom salt borax and zinc sulfate) in rates shown in Table 3 4 were applied yearly The soil on this site is a member of the thixotropic, isothermic family of Hydric Dystrandepts

[a]Source Ikawa 1979

[b]Patrick Ching personal communication

Table 3 1 (continued) Description of geographical positions and history of soil use of the experimental sites

Sites	Geographical position and history of soil use
Waipio	This site is situated on the Island of Oahu, Hawaii, approximately 8 km north of Waipahu and approximately 225 m east of the road leading to Mililani Cemetery from Kamehameha Highway The elevation was 150 m It is on nearly level upland (2 percent slope)
	The land was an abandoned pineapple field and was used to conduct maize transfer experiments in 1978 after which it was left fallow until 1982 when cropping systems experiments were started and the fertilizers (lime epsom salt, borax and zinc sulfate) of rates shown in Table 3 4 were applied yearly The soil on this site is a member of the clayey, kaolinitic isohyperthermic family of Tropeptic Eutrustox
Molokai	This site is situated in Maunaloa, Island of Molokai, Hawaii, approximately 1 5 km north-northwest of the Maunaloa Village and approximately 900 m northwest of highway 46 It is at approximately 257 m elevation on gently sloping upland (5 percent)
	The soil was formerly grown to sugarcane Maize transfer experiments were conducted in 1980 after which it was left fallow until 1982 when the cropping systems experiments were started and the fertilizers (lime, epsom salt, borax and zinc sulfate) in rates shown in Table 3 4 were applied yearly The soil on this site is a member of the clayey kaolinitic isohyperthermic family of Tropeptic Eutrustox

Table 3 2

Soil family properties as they relate to the taxa in Soil Taxonomy

Taxonomic name	Inherent soil family characteristics
Thixotropic, isothermic Hydric Dystrandepts	
thixotropic	High surface activity of colloids
isothermic	Cool soil temperatures (mean annual temperature 15-22°C)
Hydric	Moist humid soils
Dystr-	Low base saturation (< 35%)
-andept	Low bulk density (< 0 85 g cc^{-1}), amorphous colloids
Clayey kaolinitic, isohyperthermic Tropeptic Eutrustox	
clayey	More than 35% clay in the subsoil
kaolinitic	Dominated by low activity clay
isohyperthermic	Warm soil temperatures throughout the year (mean > 22°C), small difference between summer and winter temperatures (< 5°C)
Tropeptic	Moderate structure or less than 125 cm deep, or both
Eutr-	Moderately enriched with nutrients medium to high base saturation (>50%)
-ust-	Pronounced dry season (dry for more than 90 cumulative days per year)
-ox	Presence of oxides of iron and aluminum low cation-exchange capacity

Source Benchmark Soils Project 1979

Table 3 3

Some physıcal and chemıcal propertıes of the soıls at four experımental sıtes (a) Kukaıau, (b) Iole, (c) Molokaı and (d) Waıpıo

(a)

S l n me K ka u   Cl s f at   Hsd ı D st d pt th t p th c
So l   SHA 1 1   Loc t   Ho ka Isl n l f Ha   Ha

Depth	Hor zon	Particle s an lys s: Sand 05	Silt 05- 002	Clay 002	B lk dens ty	Wat r content: 1 bar	3 bar	15-bar	Orga c C	Total N	C/N	E tra tabl ron: Fe	Fe O
m		p t 2			u		p		pct			p t	
0 1	Ap1								7 34	0 80	9	10 93	15 63
17 23	Ap2								6 53	0 66	10	10 84	15 50
23 42	B21								5 68	0 56	10	10 86	15 53
42 60	B22								5 16	0 47	11	9 64	13 78
60 100	B23								4 63	0 42	11	9 51	13 60
100 130	B24								3 57	0 35	10	14 08	20 13
130 160	B25								5 97	0 53	11	10 90	15 58

Depth	E tractable bases: Ca	Mg	Na	K	Sum	Extractable acid	Cation-e change capacity: NH OAc	Sum	E tractable Al	Base saturation: NH OAc	Sum	pH: H O	KCl	Difference
m					meq 100 u l					pct				
0-17	2 53	0 03	0 12	0 51	3 19	56 22	58 69	59 41	< 0 01	5	5	6 00	5 35	0 65
1 23	1 92	0 01	0 06	0 05	2 04	55 26	67 8	57 30	< 0 01	3	4	6 10	5 45	0 85
3 42	1 91	0 01	0 10	0 03	2 05	55 07	78 86	57 12	< 0 01	2	4	6 28	5 60	0 68
42 60	1 99	0 01	0 18	0 03	2 21	47 07	67 04	49 28	< 0 01	3	4	6 40	5 80	0 60
60-100	3 33	0 02	0 24	0 05	3 64	44 33	67 26	47 97	< 0 01	5	8	6 52	5 80	0 2
100-130	3 51	0 02	0 37	0 05	3 95	39 75	48 93	43 70	< 0 01	8	9	00	6 00	1 00
130-160	6 17	0 03	0 17	0 03	6 40	57 61	100 61	64 21	< 0 01	6	10	6	6 10	-0 42

(b)

S l m N l   Class ficat n H d c Dyst an l pt th tr p th m
S l u   SHA 1 2   Loc t n N rth K hala Isl nd f Ha   H w

Depth	Horizon	Part cle ze analys s: S d 2 05	S lt 05- 002	Clay 002	Bulk den ty	W ter cont nt: 1 bar	3 bar	15 b	Organ c C	Tot l N	C N	E tr ct bl ron: F	Fe O
m		pct < mm			g c		t l		pct			p t	
0 17	Ap1								8 12	0 72	11	10 92	15 61
17 9	B21								5 04	0 39	13	11 42	16 33
9 48	B2								4 35	0 46	9	11 51	6 46
48 79	B 3								5 52	0 40	14	8 18	11 69
9 107	IIC								4 04	0 66	6	4 5	6 08

Depth	E t actable b ses: Ca	Mg	N	K	Sum	E tractable d	Cat on-e change pa ity: NH OAc	Sum	E t actable Al	Ba s tur tion: NH OA	Sum	pH: H O	KCl	D ffe ence
m					q 100 g l					p t				
0 17	7 93	0 94	0 7	0 86	10 00	6 26	64 6	36 6	0 02	15	8	6 01	4 90	1 11
17 29	0 38	0 01	0 3	0 0	0 69	46 60	56 21	4 9	0 68	1	1	5 2	4 56	1 66
29 48	1 03	0 01	0 15	0 02	1 1	41 84	55 0	43 05	0 37		3	5 20	4 80	0 40
48 9	0 17	0 01	0 10	0 04	0 32	56 61	80 54	56 93	1 9	1	1	5 0	5 02	0 18
9 107	0 13	< 0 01	0 10	0 03	0 7	4 0	80 66	—	0 19	1	1	5 08	4 99	0 09

Source Ikawa 1979

Table 3 3 (continued) Some physical and chemical properties of the soils at four experimental sites (a) Kukaiau (b) Iole, (c) Molokai, (d) Waipio

(c)

S i t Lah n t h t Cl s f Ir p t F t l t i t
S l HA 1 L c t M n l I I I I M I k H

Depth	Horizon	Particle s ze nals s: Sand 2 05	Silt 05-002	Clas 002	B lk de s t	Wat co t t: 1 b	3 ba	15 b	O ga c C	Total N	C.N	E tractable ron: F	F O
m			pct mm		g		1 1		p t			pct	
0 16	Apl								3 3	0 28	13		
16 33	Ap								1	0 10	l		
33 5	B 1								1 02	0 18	6		
9	B								0 0	0 08	9		
9 117	B23								1 1	0 09	13		
11 140	B 4								0 91	0 04	3		
140 160	B 5								0 84	0 04	1		

Depth	Extractable bases: Ca	Mg	Na	K	Sum	E t act ble d	Cat n ha g capac t: NH OA	S m	E t i ble Al	B e satu at on: NH OAc	S m	pH: H O	KCl	Difference
m					meq 100 g l					p t				
0 16	5 52	9	0 15	2 07	10 03	9 96	19 4	9 99	0 0	1	0	5 49	4 88	0 61
16 33	4 51	1 01	0 18	1 21	6 91	9 92	1 10	16 83	0 08	46	41	33	4 85	0 48
33 55	4 45	1 6	0 17	0 38	6 6	5 1	1 8	1 3	—	1	2	6 14	62	0 52
95	4 01	2 14	0 16	0 51	6 82	63	13	4	—	0	55	6 6	6 33	0 43
95 117	3 13	1	0 15	0 92	5 97	8	6 4	11	—	3	3	6 2	5 3	0 39
117 140	2 80	1 0	0 19	1 60	6 29	6 3	15 91	1 16	—	40	0	5 90	5 68	0 2
140 160	2 82	1 9	0 35	1 09	6 05	38	10 1	13 43	1 01	9	45	88	5 51	0 37

(d)

S l me W h Class f t n Tr p pt F t l i t
S l o HA 1 l cat n W p l l n l (O h H

Depth	Horizon	Particle ze nalys: Sand 2 05	S lt 05-002	Clay < 002	Bulk d n tv	W t r nt nt: 1 ba	3 b	15 bar	O gan c C	Total N	C N	E t actable ron: Fe	F O
m			pct 2 mm		g		1 1		pct			p t	
0 10	Apl	9 9	30 3	9 8						0 32		8 51	1 18
10 27	Ap2	8 5	8 6	2 9					1	0 6		5	10 75
7 40	AB	8 5	35 7	55 8					1 41	0 4	6		11 03
40 65	B21	8 2	39 4	5 4					0 59	0 14	4	8 10	11 58
65 90	B22	1 6	4 8	3 6					0 36	0 11	3	9	13 93
90 1 0	B23	4 2	0 9	4 9					0 27	0 08	3	30	10 43
1 0 150	B24	6 4	3	9 9					0 4	0 08	3	9 56	13 68

D pth	E tract ble b ses: C	Mg	N	K	Sum	E t ct ble c d	C t -e ch g p t: NH OAc	S m	E t i bl Al	Base sat rati n: NH OA	Sum	pH: H O	KCl	D ff rence
m					m q 100 g s l					pct				
0 10	6 52	4 35	0 17	2 69	13 3	9 16	0 81	99	0 03	66	0	5 41	4 80	0 61
10 27	4 93	38	0 10	0 85	8 4	11 48	18 43	19	0 30	45	4	4 95	4 18	0
7 40	6 07	3 05	0 12	0 11	9 35	9 93	1 8	19 8	0 05	53	48	31	4 48	0 83
40 65	5 8	3 13	0 12	0 0	8 3	6 6	13 4	4 99	1 03	4	58	8	5 13	0 65
5 90	4 8	3 64	0 13	0 23	8 8		3 01	13	—	7	63	6 12	61	1 51
0 1 0	4 77	3 88	0 16	0 21	8 82	4 9	14 11	13 61	—	2	65	6 27	7	0 50
0 150	5 19	3 46	0 38	0 38	9 39	4 1	14 42	14 13	—	65	68	37	5 85	0 52

The variety used in the study was White Leaf' The seeds were obtained from Zsang and Ma, Belmont, California

Cassava belongs to the family Euphorbiaceae which also include para rubber It is a short-lived shrub, 1-5 m in height, with latex in all its parts (Purseglove 1974a) It is known for its edible roots but young leaves are also consumed in different parts of the world Leaves are variable in size, color of stipules, petioles, midribs and lamina, in number of lobes depth of lobing and in shape and width of lobes The cassava used in this study had leaves with 5-7 lobes mid-ribs and veins were green in color The plants were approximately 2 m tall when the leaves were sampled

Taro belongs to the Araceae family Like cassava, it is well known for its starchy underground part and the leaves are also consumed in many parts of the world The plants can grow to 1-2 m tall, with underground starchy corm, producing at its apex a whorl of large leaves with long erect petioles The leaves are peltate 20-50 cm long, oblong-ovate glabrous, with rounded basal lobes The petioles are stout 1 m or more long and clasping at their bases (Purseglove, 1974b)

The variety used in this study was Miyako which is probably native of Japan (Whitney et al 1939) It is a short variety, shorter than 1 m, with erect and moderately stocky structure The leaf blades are 35-50 cm long, 25-35 cm wide 30-40 cm from tip to base of sinus ovate, firm-chartaceous dark green with a bluish cast the lobes are wide and obtuse with shallow wide sinus

3 3 Experiments

3 3 1 Amaranth field experiments

The field experiments were installed in Waipio Iole and Kukaiau to represent a range of agroenvironments

In addition to the effect of natural environmental factors on plant chemical composition, imposed management factors can also affect the nutrient and antinutrient contents of farm crops Two factors which farmers frequently control are water supply and nutrient supply To assess the effect of water supply on plant chemical composition, irrigated and non-irrigated experiments were conducted on each site Water was supplied to the irrigated experiments with drip irrigation The duration and frequency of irrigation were left to the discretion of project staff In general, soil conditions were used as the main criterion to decide whether irrigation was required or not Within each irrigation experiment, treatments to test the effect of nitrogen (N) or phosphorus (P) application on plant compositions were included The fertilizer treatments consisted of

1) a basal treatment of lime, N P K bases and trace nutrients (Table 3 4)
2) a N treatment superimposed on the basal treatment designated basal+N (Table 3 5), and
3) a P treatment superimposed on the basal treatment designated basal+P (Table 3 5)

These fertilizer treatments were arranged in randomized complete block design with 3 replications within each irrigation treatment Therefore there were 9 plots of irrigated experiments and 9 plots of non-irrigated experiments The plot size was 1 5 x 1 m^2

Lime, epsom salt borax and zinc sulfate (Table 3 4) were applied on an annual basis as a part of the routine operation of cropping systems experiments These materials were applied before the amaranth experiments were installed Urea, triple superphosphate and muriate of potash (Table 3 4) were applied 1-2 days prior to the planting of the amaranth The lime rates were adjusted so that the resulting soil pH would be near pH 6 Higher lime rates were applied on Hydric Dystrandepts than on the Tropeptic Eutrustox (Table 3 4) because the former has a higher buffering capacity The rates of various nutrients in the basal fertilizers applied (Table 3 4) were adjusted to provide adequate nutrients for good growth The rates of N and P fertilizer applied at planting and as a sidedressing (Table 3 5) were calculated in such a way that the response of plants to these fertilizer treatments would be reflected in their yields and chemical compositions A higher P rate was applied to the Hydric Dystrandepts soils than the Tropeptic Eutrustox soil because the former is known to fix P more than the latter Response to P fertilizer was expected from plants grown on the Hydric Dystrandepts soil, while responses to N or both N and P were expected from plants grown on the Tropeptic Eutrustox soil

At all locations the land was ploughed to 15 cm depth before the fertilizer was applied All fertilizers used were of commercial grade All basal fertilizers and lime (Table 3 4) and N and P fertilizers applied at planting (Table 3 5) were broadcast by hand before being worked into the soil The plants were sidedressed with N fertilizer

(Table 3 5) after the plants had emerged and had been thinned to required spacing The fertilizer was applied by hand, close to the plants and covered with soil

Table 3 4

Forms and rates of basal fertilizers and lime used in the amaranth experiments

Element	Chemical formula (Common name)	Rate (kg element ha^{-1})	
		Hydric Dystrandepts	Tropeptic Eutrustox
Ca	$CaCO_3$ (lime)	1000	750
Mg	$MgSO_4$ $7H_2O$ (epsom salt)	100	100
B	$Na_2B_4O_7$ $10H_2O$ (borax)	5	2
Zn	$ZnSO_4$ H_2O	15	15
N	$CO(NH_2)_2$ (urea)	50	50
P	$CaH_4(PO_4)_2$ H_2O (triple superphosphate)	25	25
K	KCL (muriate of potash)	170	100

After the application of lime basal and preplant fertilizers seeds were dropped by hand into furrows at 2 5 cm deep No attempt was made to space the seeds as they were to be thinned to the required

Table 3 5

Rates and timing of application of N and P fertilizers in addition to basal in amaranth experiments

Site	Treatment	Rate (kg element ha^{-1})			
		Preplant (Basal)	At planting	Sidedress	Total
Iole and Kukaiau	N	50	100	100	250
	P	25	200	-	225
Waipio	N	50	100	100	250
	P	25	120	-	145

spacing later There were 5 rows spaced 16 6 cm apart in each plot The edge rows were used as guard rows

In most cases the seeds emerged to form a thick stand At the two- to four-leaf stage they were thinned to a linear density of one plant per 15 cm resulting in 11 plants per row leaving 55 plants per plot

In Waipio non-irrigated plots the plants did not emerge until approximately 2 months after sowing Emergence followed 15 mm of rains which fell during March 8-15 1983 and the growth was sustained by 54 1 mm of rains which fell from March 16 to April 27 1983 The insecticide Sevin was applied to all Waipio plants when they were approximately 1 month old to minimize insect damage In Waipio irrigated plots the plants emerged seven to ten days after seed sowing

In Iole, plants in both the irrigated and non-irrigated treatments grew poorly The seedlings emerged ununiformly and several weeks late and the plant growth was not uniform within the same plot The emergence and growth were poorer in the irrigated plots than in the non-irrigated ones However the plants in both experiments did respond to P fertilizer treatment (basal+P) where the plants were larger than those receiving the other fertilizer treatments

In Kukaiau the plants in both irrigated and non-irrigated plots emerged uniformly and grew vigorously Responses to fertilizer treatments, especially P, were clearly evident

The experiments at each location were monitored by the project staff who also determined water requirements for the irrigated treatment They also recorded the general conditions of the experiments

The plants were harvested when the flower buds were apparent An attempt was made to harvest the plants in all experiments at the same physiological stage Due to the uneven emergence and growth in several treatments, all treatments were not harvested at the same time as shown in Table 3 6 The uneven emergence and growth rate resulted in exposures to different sets of environmental conditions for experiments conducted at the same site

With the exception of the irrigated treatment at Iole which produced less than 10 plants (Table 3 7) 10 representative plants from each plot (judged on their appearance i e , height leaf and stem size physiological stage such as appearance of flower buds) were sampled for analysis

Table 3.6

Growing durations of amaranth grown in six experiments at three sites

	Kukaiau		Iole		Waipio	
	NI*	I*	NI*	I*	NI*	I*
Planting date	1/29/83	1/29/83	1/29/83	1/29/83	1/13/83	1/13/83
Harvesting date	4/10/83	4/10/83	5/4/83	6/28/83	6/23/83	3/24/83
Growing duration (days)	71	71	95	150	161	70
Number of plants harvested/plot	10	10	10	<10	10	10
Physiological stage and appearance at harvest	flower buds	flower buds	flower buds	flower buds some at seeding stage	flower buds small leaves	flower buds

*NI = Non-irrigated treatment I = Irrigated treatment

Table 3 7

Number of amaranth plants harvested from Iole irrigated experiment

Plot #	Fertilizer treatment	Replication	No of plants	Fresh weight (g)	Physiological stage
1	Basal	1	1	35	Seeding
2		2	1	232	Flowering
3		3	6	46	Flowering+seeding
4	Basal+N	1	6	256	Flowering
5		2	3	501	Flowering
6		3	0	0	-
7	Basal+P	1	9	833	Flowering
8		2	3	64	Flowering
9		3	4	134	Flowering

The plants were cut at the soil level and placed in polyethylene bags for transportation to the laboratory At the laboratory they were washed free of dust and soil with tap water and again with distilled water and blot-dried with paper towels After washing and towel drying, they were weighed to obtain fresh weights

The edible parts consisting of leaves and young succulent shoots, were separated from the non-edible hard and fibrous stems and branches The edible parts were stored in sealed polyethylene bags and stored in the freezers for later analysis

3 3 2 Cassava

Cassava leaves were sampled from the Tropeptic Eutrustox soils at Waipio and Molokai and from the Hydric Dystrandepts soils at Kukaiau and Iole At all sites cassava was grown in hedge rows as wind breaks for other crops in the cropping systems experiments as illustrated in Figure 3 1

In the Waipio and Molokai sites casssava was grown in irrigated and non-irrigated plots, whereas in Kukaiau and Iole all plants were irrigated Cassava is a drought resistant crop, therefore, it was expected to be able to thrive without irrigation in areas with low rainfall such as in Waipio and Molokai

The youngest fully expanded leaves (i e , the third or fourth leaf from the top) including petioles were harvested from each branch for a total of 50 leaves from each sampling location of the cropping pattern described in Figure 3 1 The 50 leaves from each location constituted a composite sample Two composite samples were collected from each of two rows in Waipio and Molokai with Tropeptic Eutrustox soils, whereas three composite samples were collected from each of two rows in Kukaiau and Iole with Hydric Dystrandepts soils Table 3 8 shows the age and sampling date of the cassava experiments

The leaf samples were placed in plastic bags and transported to the laboratory where they were washed with tap and then distilled water to remove dust and soil, blotted-dried weighed to determine fresh weights and frozen

3 3 3 <u>Taro</u>

Taro leaves were sampled from the irrigated and non-irrigated plots at both the Kukaiau and Iole sites No taro was grown at the Molokai site and all taro plants received irrigation water at Waipio owing to the low rainfall there

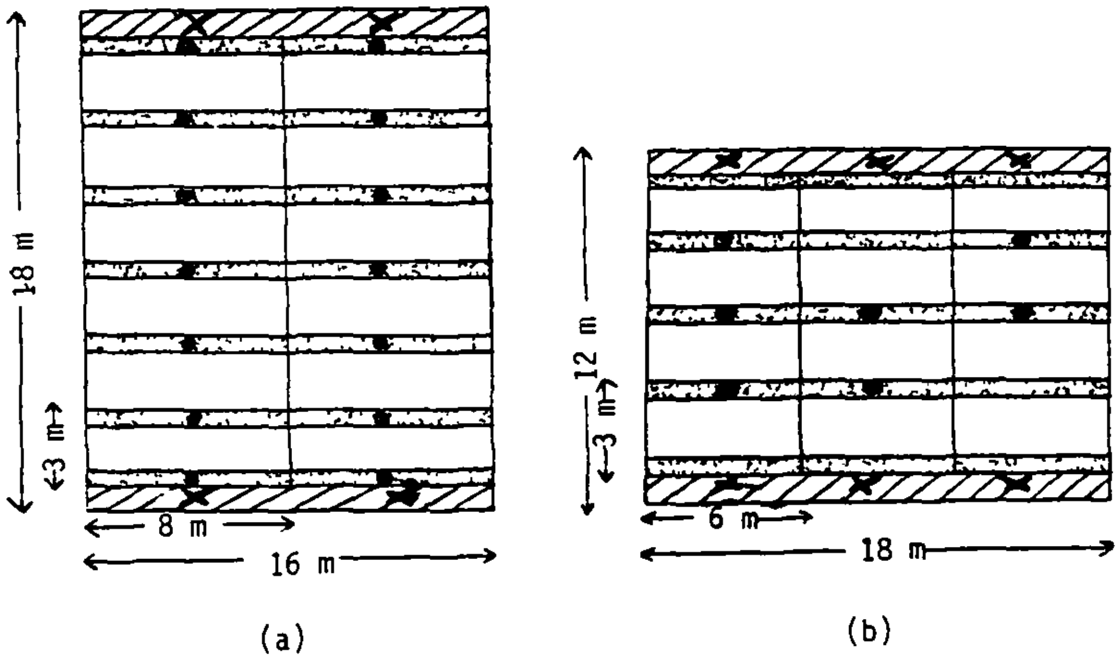


Figure 3 1 Cropping patterns for Tropeptic Eutrustox sites (a) and Hydric Dystrandepts sites (b) showing locations of cassava (▨) and taro (□) rows and sampling locations for cassava (X) and taro (●)

Table 3 8

Planting date, sampling date and age of cassava crops at sampling

Site	Planting date	Sampling date	Plant age (weeks)
Kukaiau	1/19/82	11/ 4/82	42
Iole	1/22/82	11/ 4/82	41
Waipio	2/17/82	11/ 1/82	37
Molokai	2/22/82	10/19/82	35

For analysis the youngest fully developed leaf was cut close to the blade to exclude the petiole Each composite sample of eight leaves was collected from each row as of the cropping pattern described in Figure 3 1

Fourteen samples were collected from the Waipio site and seven samples per experiment were collected from the Kukaiau and Iole sites for a total of 14 samples per site

Table 3 9 gives the age and sampling date of the taro experiments Each taro sample was cleaned and stored the same way as cassava leaves

3 4 Laboratory analyses

This study involved many laboratory techniques, which were standardized and described in other publications and are mentioned briefly in this section However the fractionation of oxalates from plant tissue and their measurements by the high performance liquid chromatography (HPLC) technique was newly developed in this study in

Table 3 9

Planting date sampling date and age of taro crops at sampling

Site	Planting date	Sampling date	Age at sampling date (weeks)
Kukaiau	4/13/82	11/4/82	29
Iole	4/14/82	11/4/82	29
Waipio	5/3/82	11/1/82	26

order to obtain data for objectives 1 and 3 of this study The techniques are described in section 3 6

3 4 1 Plant

Determination of dry weight and moisture content of plant tissue

To obtain moisture content of plant tissue (edible part) and at the same time to obtain dry plant material for chemical analyses the frozen plant materials were freeze-dried at 40°C Freeze-drying is an effective technique to obtain dry plant material for analysis of organic compounds Through this technique plant material can be dried at low temperatures thus avoiding changes in organic compounds

The moisture contents of edible parts of amaranth were obtained by subtracting the freeze-dried weights from the frozen weights Dry weights of harvested plants (10 plants) were then calculated from their fresh weights and the corresponding moisture contents In the case of the Iole irrigated plants, after the dry weight per plot was obtained, the value was adjusted to represent the 10 plants, because less than 10 plants were harvested from these plots (Table 3 7)

Moisture contents of cassava and taro were obtained by subtracting the freeze-dried weight from the fresh weight

The freeze-dried plant materials were ground to fine powder for further chemical analyses

Determination of sap pH

Approximately 1 g of freeze-dried ground plant material was mixed with 10 g of deionized water for pH measurement

Determination of total nitrogen in plant tissue

Total-N in plant tissue was digested in a micro-Kjeldahl apparatus and measured by a colorimetric procedure using a Technicon autoanalyzer (Clements, 1980)

Determination of ionic and trace element contents in plant tissue

Concentrations of Cations (Ca, Mg, K, and Na) and anions (P ($H_3PO_4^-$), S (SO_4^{2-}) and Cl), and some trace elements including Al, Mn, Zn, Cu, Fe and Si were determined by a x-ray fluorescence spectrometer, model 72 000 manufactured by Applied Research Laboratories

Nitrate-N was determined by the H_2SO_4-salicylic acid method (Cataldo et al , 1975) Boron was determined by automated carminic acid-phenol method (Clements 1980) The technicon autoanalyzer was used as the main analytical apparatus for both nitrate-N and B determinations

The concentrations of all major cations and anions were expressed in the units of cmol kg^{-1} on a dry weight basis which is identical to the unit of me/100 g on a dry weight basis, for comparative (ionic balance study) purposes and as percent of dry weight for general quantitative purposes

Determination of oxalate in plant tissue

This consisted of the extraction of the total as well as various fractions of oxalate and the subsequent measurement of oxalic acid concentrations by the HPLC technique The detailed procedures are described in section 3 6

The concentrations of oxalates were expressed in cmol kg^{-1} on a dry weight basis and percent of dry weight for the purposes stated earlier

Determination of bases in the oxalate fractionation extracts of plant tissue

The water soluble fraction and water insoluble but acid soluble fraction were analyzed for Ca, Mg, K and Na concentrations Ca and Mg were determined in an atomic absorption spectrophotometer (Perkin and Elmer Model 303) and K and Na on a flame photometer (Coleman Junior II, Model 6/20) The concentrations were expressed as cmol kg^{-1} on a dry weight basis

3 4 2 Soils

To characterize the agroenvironment further soil chemical analyses for their total N exchangable bases and P contents were conducted Soil samples from only the amaranth plots were chemically analyzed Soil data for cassava and taro were obtained from the soil analysis of 1983 of the Benchmark Soils Project

Determination of total-nitrogen in soils

The total-N in soils was determined using the micro-Kjeldahl method (Soil Conservation Service USDA, 1972) Soil samples weighing 0 5-1 g and a catalyst mixture of K_2SO_4 $FeSO_4$ $CuSO_4$ Se=7 9 1 1 0 1 by weight were used Ammonia was collected in boric acid and titrated with 0 0371 or 0 0519 N H_2SO_4 depending on the N concentrations This method of total-N determination did not include NO_3-N

Determination of exchangeable bases in soils

Exchangeable bases (i e , Ca, Mg, K and Na) were extracted from 10 g of air-dried soils with 15 ml of 1 N NH_4OAc After the extract was filtered, the filtrate volume was made up to 100 ml (Soil Conservation Service USDA, 1972) Calcium and Mg were determined by atomic absorption spectrophotometry and K and Na by flame photometry

Determination of extractable phosphate in soils

One gram of oven-dried soil was extracted with 100 ml of modified Truog extractant (0 025 N H_2SO_4+0 38% $(NH_4)_2SO_4$) Phosphorus concentration was determined colorimetrically using ammonium paramolybdate and ascorbic acid as color developer (Ayres and Hagihara 1952, Olsen and Sommers, 1982)

3 5 Data analysis

The Statistical Analysis System (SAS) computer package was used for the analysis of variance, means comparisons and correlation and regression analyses

In amaranth the fertilizer treatments within each irrigation experiment were arranged in a randomized complete block design and analyzed accordingly The effects of irrigation fertilizer and their interactions at each site were analyzed as if the experiment was a split plot design with irrigation as the main plots and fertilizer treatments as the subplots The difficulty in randomizing the irrigation treatment necessitated this approach and therefore the interpretation of the statistical analysis requires some caution

The effects of sites and various interactions were analyzed using the split split plot design with site as the main plots, irrigation as the subplots and fertilizer as the sub-subplots

For the cassava study, all sites had irrigated experiments but only the Molokai and Waipio sites had both irrigated and non-irrigated trials In the taro study, the Kukaiau and Iole sites had both irrigated and non-irrigated experiments wheras the Waipio site had only irrigated experiments No taro experiment was conducted at the Molokai site Since the irrigated experiments were conducted at all sites the effect of site on plant chemical composition was tested on data collected from the irrigated experiments

The effect of irrigation was analyzed for each site containing both types of experiments, and the effect of site by irrigation interaction was obtained by combining the irrigated and non-irrigated cassava experiments from the Waipio and Molokai sites and by combining the irrigated and non-irrigated taro experiments from Kukaiau and Iole

The Duncan-Waller s multiple range test was used for comparing the effects of site and fertilizer on amaranth and the effect of site on cassava and taro This test is appropriate for cases with unequal subclass numbers as was the case with the cassava and taro experiments

In order to evaluate results affected by treatment interactions the least significant difference (LSD) analysis was employed because the Duncan-Waller's multiple range tests only compare main effects

The relationships between various plant, soil and weather variables were investigated through correlation and regression techniques Multiple regression models were used to assess the effects of climatic and soil variables on oxalate and nitrate contents of amaranth cassava and taro

3 6 Development of methods for oxalate extraction fractionation and determination

The development of these methods was designed to meet the conditions for organic acid determination by high performance liquid chromatography (HPLC)

3 6 1 Extraction of total oxalate from plant tissue

This was essentially the standard technique described in AOAC (Horwitz, 1975) with minor modifications

Freeze-dried, finely ground plant material weighing 2 5 g was boiled for 30 minutes in 300 ml of 1 1 N HCl (55 ml 6 N HCl and 245 ml distilled water) Two to three drops of caprylic alcohol were added to prevent foaming during boiling

The boiled mixture was allowed to cool to room temperature and its volume subsequently adjusted to 500 ml with distilled water It was then filtered through Whatman #541 filter paper The first 100 ml of the filtrate was discarded and the remaining filtrate was stored in a refrigerator at 4^{o}C for subsequent oxalate determination by the HPLC technique

3 6 2 Extraction of oxalate fractions

Previous findings such as those of Baker (1952), Moir (1953), Singh and Saxena (1972) and Hodgkinson (1977), suggest that oxalates should be fractionated into 3 parts, namely free oxalic acid, hot water soluble oxalate and hot acid soluble (hot water insoluble) oxalate

Free oxalic acid is known to be highly soluble in ethanol at room temperature, while the other forms of oxalate, such as K-, Ca- Mg-, Na- and NH_4-oxalates are insoluble (Weast 1973) Thus, ethanol was used to extract free oxalic acid

Potassium- Na-, NH_4-oxalates and to a lesser extent Mg oxalate are known to be water soluble and their solubilities increase with increasing temperature (Weast 1973, Hodgkinson, 1977) Boiling water was, therefore used to extract this fraction

Calcium oxalate and to a lesser extent Mg oxalate are known to be relatively insoluble in water (Weast 1973, Hodgkinson 1977) Therefore hot acid, similar to that used to extract total oxalate was used to extract this fraction

Procedure for extraction of oxalate fractions

Freeze-dried, finely ground plant material weighing one gram was shaken for one hour in 30 ml of 95% ethanol The mixture was filtered through ashless filter paper and subsequently washed with ethanol The filtrate was made to 100 ml volume with ethanol This extract was used for free oxalic acid determination

The plant residue on the filter paper was dried to room temperature and was transferred into a 600 ml beaker One hundred ml of distilled water were added to the beaker along with two to three drops of caprylic alcohol to prevent foaming The mixture was boiled for 30 minutes After cooling to room temperature it was filtered through fast, ashless filter paper into a 200-ml volumetric flask The volume was made up with distilled water This extract was used for the determination of water soluble oxalate, Ca, Mg, K and Na contents

The wet plant residue on the filter paper was transferred to a 1000-ml beaker along with 150 ml of distilled water 27 5 ml 6 N HCl and a few drops of caprylic alcohol The mixture was boiled for 30 minutes After cooling to room temperature the content was poured into a 250-ml volumetric flask and the volume was made up with distilled water The content in 250-ml volumetric flask was filtered through fast, ashless filter paper (Whatman #541) The first 100 ml of the filtrate was discarded and the remainder was kept for determination of insoluble oxalate Ca, Mg, K, and Na contents

3 6 3 Preparation of the samples from the different oxalate fraction for HPLC analysis

An aliquot of 1-2 ml from each extract was pipetted into a test tube With the exception of the alcohol extract, all aliquots were evaporated to dryness in a vacuum oven at 40-42^{o}C This process took approximately 5-8 hours The aliquots from the alcohol extract were evaporated in an air convection oven at 40^{o}C The dry residues were dissolved in 10 ml of 0 013 N H_2SO_4 since this acid was also used as the standard eluent (mobile phase) for the ion exchange column of the HPLC

After each residue was dissolved in 0 013 N H_2SO_4 the solution was filtered through Whatman #1 filter paper and refiltered through a special filter 'Sep Pak , manufactured specifically for HPLC use The solution prepared from ethanol extract required several refilterings with Sep Pak' (Water Assoc , Mass) to remove color The final solution prior to analysis by HPLC was clear and colorless The samples were frozen if an immediate HPLC run was not possible

3 6 4 Description of oxalate determination by HPLC technique

The instrument which is called collectively HPLC consisted of an automatic injector, a high pressure pump a chromatographic column a detector and an integrator

The automatic injector (Micromeritics Model 725, Norcross Georgia 30093) enables the samples to be fed to the system automatically Approximately 0 8 ml was required from each sample The samples were placed in special glass vials with a tightly fitting plastic stopper The stoppered vials containing the samples were arranged in a self-revolving tray attached to the injector A needle which automatically penetrated the plastic stopper of the vial fed sample solutions to the column

The column pressure was maintained between 1500-1850 psi with a Beckman solvent metering pump Model 110A The pressure is determined by the flow rate and the chemical nature of the mobile phase In most cases the flow rate was maintained at 0 6-0 8 ml/minute

The chromatographic column is known as an ion exchange column It detects and measures organic acids by ion exclusion and partition chromatography by means of a strong cation exchange resin Aminex ion exclusion HPX-87, manufactured by BIO-RAD In general organic acids emerge from the column in the order of increasing pKa when dilute sulfuric acid is used as the solvent

The detector used was a combination of the Model 100-10 Hitachi spectrophotometer and Beckman's Altex spectrophotometer flow cells The combination results in a high performance variable wavelength absorbance detector for use in liquid chromatography For organic acid analysis, the UV wavelength of 210 nm was used

A small, single-channel plotting/reporting integrator Model 3390A Hewlett and Packard was also a part of the assembly

Minor modification of the procedures

High nitrate content in the leaf tissue interfered with oxalate determination by the HPLC column Nitrate and oxalate have the same absorbance wavelength (210 nm) and their retention times are very close, especially when 0 013 N H_2SO_4 is used as the eluent This eluent did not permit the complete separation of oxalate and NO_3 Better separation was achieved when more concentrated sulfuric acid (i e 0 05 N) was used However, when the column was replaced with a new one of the same specification, it was found that 0 05 N H_2SO_4 by itself was not sufficient to separate NO_3 and oxalate The use of 5% acetonitrile with 0 05 N H_2SO_4 resulted in better separation of oxalate and NO_3 However acetonitrile shortened the life span of the column

Use of an internal standard to study oxalate recovery from HPLC determination

During each HPLC run, recovery study was run simultaneously, by using an internal standard For this purpose 0 1 ml of 1 000 ppm standard oxalic acid was added to a two ml aliquot of plant extract This spiked' sample (Figure 3 2) was run in duplicate The rest of the procedure remained the same as described in section 3 6 3 The 10 ml spiked sample (section 3 6 3) contains oxalic acid from the plant extract and internal standard As shown in Figure 3 2, the addition of 0 1 ml of 1,000-ppm oxalic acid should result in a 10 ppm higher concentration for 100% recovery

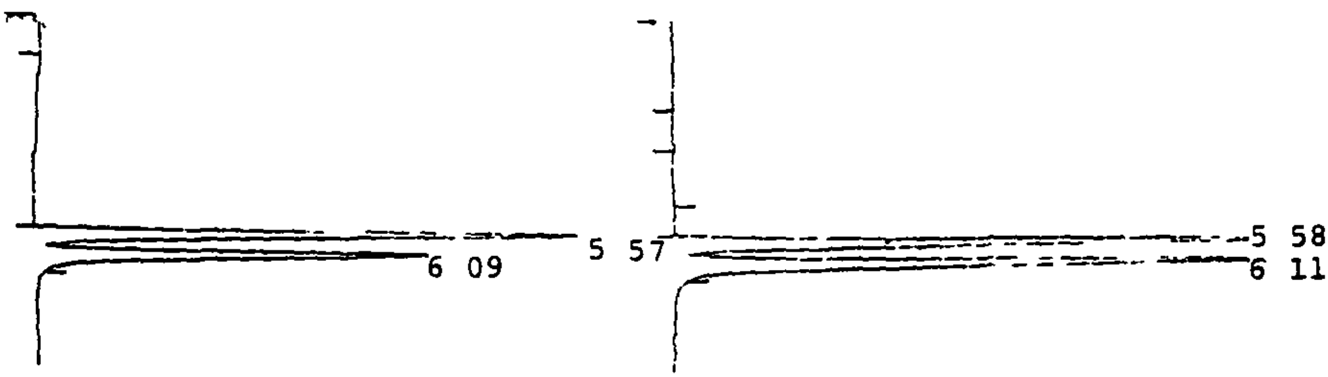
The percent recovery was calculated by taking the difference in oxalate concentration between the spiked and non-spiked sample This difference divided by the concentration of the added internal standard is the fraction recovered This value was used to adjust all HPLC reading to 100% oxalate recovery

3 6 5 Comparison of the classical and HPLC methods of oxalate determination

In order to measure the several forms of oxalate in plant tissue, it is necessary to use sensitive methods of analyses In this experiment the recoveries of various forms of oxalate using the classical and HPLC methods of oxalate determination were compared Analytical grades of oxalic acid and three forms of oxalate were used to prepare a range of solution concentrations as shown in Table 3 10 Aliquots of these working standards were analyzed by both the HPLC and classical methods

The classical procedure

The classical technique for oxalate determination (Horwitz 1975) is based on the precipitation of oxalate in the plant extract as Ca



Run #517

RT*	Area	Amount (ppm)
5 57	691950	3 394
6 09	563130	21 481

'Non-spiked'

Run #518

RT*	Area	Amount (ppm)
5 58	818160	4 013
6 11	826990	31 546

'Spiked'

Figure 3 2 HPLC chromatograms illustrating the resolution of nitrate (upper) and oxalate peaks and the difference between spiked (right) and non-spiked samples

*RT = Retention time in minutes

Table 3 10

Standard solutions of oxalic acid and oxalates

Form	Formula and formula weight	Concentration of oxalate ion ($C_2O_4^{2-}$) (ppm)					
Oxalic acid	HOCOCOOH $2H_2O$ (126 00)	1000	500	250	125	62 5	6 3
Sodium oxalate	$Na_2C_2O_4$ (134 00)	656 7	328 4	164 2	82 1	41 0	4 1
Ammonium oxalate	$(HH_4)_2C_2O_4$ H_2O (142 12)	709 0	345 5	177 2	88 6	44 3	4 4
Potassium oxalate	$K_2C_2O_4$ H_2O (184 24)	529 4	264 7	132 3	66 2	33 1	3 3

oxalate at pH 4 to 5, and the subsequent titrimetric or spectrophotometric determination of Ca

An aliquot of 20 ml of each standard oxalate solution shown in Table 3 10 was pipetted into a beaker The pH of the aliquot was adjusted to 4-4 5 with concentrated NH_4OH Then 5 ml of a calcium oxalate solution in acetate buffer (pH 4 5) were added The mixture was allowed to stand overnight at room temperature to provide enough time for Ca oxalate to precipitate This was centrifuged at 3 000 rpm for 15 minutes After removal of the supernatant liquid the precipitate was washed twice with a fine jet stream of 20 ml filtered cold wash liquid Five ml of 10% H_2SO_4 were added to dissolve the Ca oxalte and the contents quantitatively transferred and made to volume in a 25-ml volumetric flask with 1 N HCl The Ca in this solution was measured by atomic absorption spectrophotometer

The HPLC procedure

The standard oxalic acid and oxalate solution (Table 3 10) were analyzed directly without sample preparation because of their high purity The resulting peak heights are shown in Table 3 11 and related to oxalate concentration as illustrated in Figure 3 3

As shown in Table 3 12 the classical method gave good results between the range of 325-700 ppm but overestimated oxalate content below 300 ppm and underestimated the true value above 700 ppm

The HPLC method resulted in a curvilinear relationship between peak height and oxalate ion concentrations (Figure 3 3) A linear relationship was found between 0-125 ppm (Figure 3 3) The particular chromatographic column used in this experiment could not detect oxalic acid below 6 3 ppm (Table 3 12), but throughout much of this study there was evidence that this technique could determine oxalic acid concentrations as low as 2 ppm Different forms of oxalate salts had little effect on the accuracy of oxalate determinations for both techniques

This study shows that the HPLC is a good method for plant oxalates because the concentration range in plant extract samples (10-100 ppm) falls within the linear range

Table 3 11

Relationships between oxalate ion ($C_2O_4^{2-}$) concentrations and HPLC peak height

$C_2O_4^{2-}$ concentration (ppm)	Peak height (cm)
33 1	0 9
41 0	1 0
44 3	1 2
62 5	1 7
66 2	1 8
82 1	2 2
88 6	2 4
125 0	3 3
132 3	3 9
164 2	4 8
177 2	5 2
250 0	7 4
264 7	8 8
328 4	11 0
354 5	12 5
500 0	16 4

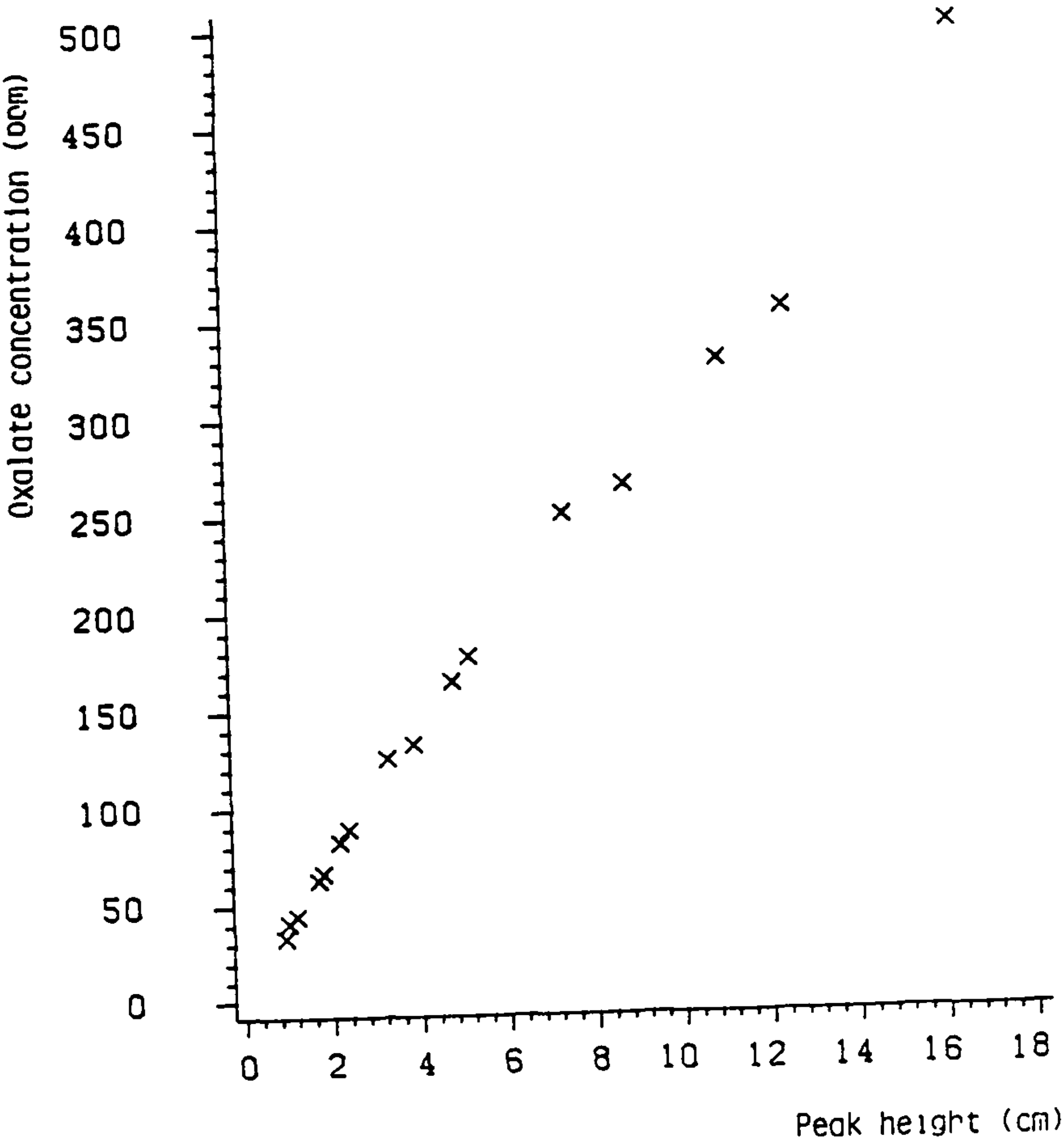


Figure 3 3 Relationship between oxalate concentration and peak height

Table 3 12

Comparison of oxalate content determined by the classical and HPLC methods

	Oxalate ion ($C_2O_4^{2-}$) concentration (ppm)		
	Standard concentration	Measured concentration	
		Classical	HPLC*
Na oxalate	656 7	663 4	-
	328 4	329 7	336 2
	164 2	192 5	157 6
	82 1	101 5	82 5
	41 0	-	37 5
	4 1	-	n d **
NH_4 oxalate	709 0	718 1	-
	354 5	350 6	378 2
	177 2	215 8	169 4
	88 6	120 0	90 0
	44 3	-	45 0
	4 4	-	n d
K oxalate	529 4	551 0	-
	264 7	275 8	273 8
	132 3	157 8	131 0
	66 2	90 6	67 5
	33 1	-	33 8
	3 3	-	n d
Oxalic acid	1000	840 0	-
	500	476 2	485 3
	250	265 7	233 5
	125	140 5	123 8
	62 5	-	63 8
	6 3	-	n d

* The regression equation $y = 0\ 1906 + 37\ 3293x$ in Figure 3 3 was used to calculate oxalate concentrations below 125 ppm but $y = 13\ 83 + 30\ 46\ x - 0\ 10\ x^2$ was used for concentrations greater than 125 ppm

** Non-detectable due to exceedingly low concentrations

3 6 6 <u>Oxalate recovery from the extraction and fractionation of plant materials</u>

This part of the study consisted of three parts which are called Recovery I, Recovery II and Mg oxalate solubility The Recovery I experiment was conducted for the purpose of assessing the recovery of total, Ca- K- and Mg oxalates from plant material using the total oxalate extraction and oxalate fractionation techniques described in sections 3 6 1 and 3 6 2 Since Mg oxalate is partially soluble in hot water, the Recovery II experiment was conducted for the purpose of assessing the recovery of only the total, Ca- and K oxalates from plant material using the technique described in sections 3 6 1 and 3 6 2 Concentrations of the internal standards used for these recovery studies are given in Table 3 13

Based on published chemical data (Weast, 1973) three assumptions were made (1) that K oxalate was totally soluble in boiling water (2) that Ca oxalate was totally insoluble in hot water but was totally soluble in hot acid, and (3) that Mg oxalate was partially soluble in hot water and also soluble in hot acid

A magnesium oxalate solubility experiment was conducted to measure the proportion of Mg oxalate which is soluble in hot water and in hot acid The results from this experiment were used to calculate recovery of Mg oxalate in the recovery I experiment The two recovery experiments made use of added internal standards as described in section 3 6 4 The experiment included a set of controls which did not receive oxalate internal standards The difference in oxalate concentration between the treated and the control samples was the added concentration of internal standards to the treated' samples Recovery was calculated as follows

$$\% \text{ recovery} = \frac{\text{ppm of 'treated sample - ppm of 'control sample}}{\text{Actual concentration (ppm) of oxalate internal standard added}} \times 100$$

Magnesium oxalate solubility experiment

Three replications of 0 0659 g of analytical grade Mg oxalate (MgC_2O_4 $2H_2O$) were weighed and placed in 250-ml beakers One hundred ml of distilled water a volume equal to the amount used to extract water soluble oxalate fractions were added to the beakers The contents were boiled for 30 minutes, cooled to room temperature, filtered through #40 Whatman filter paper into a 200-ml volumetric flask and made up to volume with distilled water This is the same treatment that was used for plant samples except that #40 filter paper was used here

A 1 ml aliquot was diluted 25 times with distilled water and magnesium was determined in this solution by atomic absorption spectrophotometry

The Mg concentration was converted to an equivalent amount of Mg oxalate This portion of Mg oxalate was considered to be water soluble By subtracting this soluble portion from the total Mg oxalate originally added the quantity of water insoluble portion was obtained

On an average 72 1% of the MgC_2O_4 $2H_2O$ was soluble in boiling water while 27 9% was insoluble (Table 3 14) These percentages were taken to represent the solubility of plant Mg oxalate However, it should be emphasized that this experiment did not simulate the true conditions of plant samples where other oxalates might interfere with the solubility of Mg oxalate The solubility obtained with reagent grade Mg oxalate may overestimate the solubility of Mg oxalate in plant materials and underestimate the amount of insoluble Mg oxalate

Recovery I experiment

Dried, ground plant material weighing 1 g was transferred to a 250-ml beaker Care was taken to keep sample weights between 1 0000± 0 0001 g to allow for direct computation of recovery from HPLC reading in ppm For the 'treated samples internal standards of 0 0409, 0 0324 and 0 0658 grams of K-, Ca- and Mg oxalates, respectively were added These quantities were pre-calculated to enable the final oxalte concentration to be read directly from the HPLC

The results showed that recoveries of the water soluble fraction and total oxalate were low, while the insoluble fraction exceeded 100% (Table 3 15) These results appear to support the concern regarding the decreasing effect that plant oxalates could have on the recovery value of Mg oxalate determined on the pure reagent grade salt

Recovery II experiment

To eliminate the uncertainty regarding the solubility of Mg oxalate in boiling water the addition of Mg oxalate crystals were excluded in the Recovery II experiment The procedures otherwise were the same as those of the recovery I experiment

The recoveries of oxalate in the water soluble and water insoluble fractions were close to 100% (Table 3 16) These recoveries are considered satisfactory and indicate that all K oxalate and Ca oxalate are recoverable by the methods of fractionation and extraction employed in this study

Table 3 13

Concentratıons of ınternal standards for three forms of oxalate used ın the recovery experıment

Oxalate fractions	K oxalate (a)	Ca oxalate (b)	Total for Recovery II (a)+(b) (ppm)	Mg oxalate (c)	Total for Recovery I (a)+(b)+(c)
Soluble oxalate	16 0	0 0	16 0	11 5*	27 5
Insoluble oxalate	0 0	8 0	8 0	4 5	12 5
Total oxalate	16 0	8 0	24 0	16 0	40 0

*Usıng 72 1% solubılıty value

Table 3 14

Solubility of magnesium oxalate in hot water

Portion of Mg oxalate	Mg oxalate	
	mg	% total
Total amount added	65 8	100 0
Boiling water soluble	46 5	72 1
Boiling water insoluble (acid soluble)	19 4	27 9*

*A preliminary experiment showed that Mg oxalate was completely soluble in hot acid

Table 3 15

Recovery of water soluble water insoluble and total oxalate (Recovery I experiment)

Treatments	Oxalate concentrations in different fractions			
	Water soluble (1)	Water insoluble (2)	Total (1)+(2)	Total analyzed
Treated[a] (ppm)	22 9	50 9	73 8	70 3
Control[a] (ppm)	13 5	26 6	40 4	41 2
Difference[a] (ppm)	9 4	24 3	33 7	29 1
Recovery (%)[a]	34 2[b]	194 4[c]	84 3[d]	72 8

a Means of 3 replicates
b Calculation (9 4/27 5) x 100
c Calculation (24 3/12 5) x 100
d Calculation (33 7/40 0) x 100

Table 3 16

Recovery of water soluble, water insoluble and total oxalate (Recovery II experiment)

Treatments	Oxalate concentrations in different fractions			
	Water soluble (1)	Water insoluble (2)	Total (1)+(2)	Total analyzed
Treated[a] (ppm)	36 2	48 8	85 0	87 2
Control[a] (ppm)	19 3	40 6	59 9	61 6
Difference[a] (ppm)	16 9	8 2	25 1	25 6
Recovery (%)[a]	105 6[b]	102 5[c]	104 6[d]	106 7

a Means of 3 replicates
b Calculation (16 9/16 0) x 100
c Calculation (8 2/ 8 0) x 100
d Calculation, (25 1/24 0) x 100

3 7 Soil and weather characteristics measured specifically for the study of agroenvironmental effects on nutritional quality of food crops

In order to characterize the agroenvironment of the experimental sites, measurement of soil and climatic components of the agroenvironments were undertaken at each site Soil data from amaranth experiments were obtained for each experimental plot but those from cassava and taro experiments were already measured and made available by the Benchmark Soils Project

The chemical analysis of the soil samples from amaranth plots were made after the plants were harvested The results of the chemical analysis of the soil for the amaranth cassava and taro (Tables 3 17

3 18) plots are comparable to the previous results of soil analysis from the same sites (Table 3 3) reported by Ikawa (1979) The Tropeptic Eutrustox soils in Molokai and Waipio had higher exchangeable bases than the Hydric Dystrandepts soils of Iole and Kukaiau as shown in Tables 3 17 and 3 18 On the other hand, the Tropeptic Eutrustox soil at Waipio had significantly lower total N content than the Hydric Dystrandepts soils of Iole and Kukaiau (Table 3 17) Higher P contents were found in the Kukaiau soil than the soils from the other sites as shown in Tables 3 17 and 3 18 This was likely residual P from previous heavy P applications on the Kukaiau soil

Since the irrigated and non-irrigated plots were not situated adjacent to each other in all three sites of amaranth experiments, the soil chemical properties of both irrigated and non-irrigated plots are presented in Table 3 19 In Kukaiau, higher total N and P were found in the irrigated than in the non-irrigated plots In Iole, higher total N was found in the irrigated plots but higher Ca and Mg concentrations were found in the non-irrigated plots In Waipio, higher concentrations of Na and P were found in the irrigated plots but Ca and K were higher in the non-irrigated plots The difference in soil chemical properties between irrigated and non-irrigated plots can result in differences in plant chemical composition

There are distinct differences regarding the climatic factors of the four experimental sites Kukaiau and Iole sites are generally wetter than the Waipio site (Tables 3 20 3 21 3 22) However the Molokai site although considered to be a dry site due to low rainfall had a higher relative humidity than the other three sites (Table 3 21)

The Kukaiau and Iole sites received lower solar radiation and had lower air and soil temperatures than the Molokai and Waipio sites (Tables 3 20, 3 21, 3 22) Both Kukaiau and Iole sites were situated in higher elevations and because of the frequent cloud cover associated with frequent rains and cool temperatures, the energy supply was lower compared to the Waipio and Molokai sites

Comparing the two sites at the Island of Hawaii, Iole tended to be cooler as indicated by lower air and topsoil temperatures and solar radiation (Tables 3 20, 3 21, 3 22) Since the non-irrigated amaranth in Waipio were left in the field much longer than its irrigated counterpart, it received almost 5 times more rain than the irrigated amaranth (Table 3 20) A similar situation was observed in Iole since irrigated and non-irrigated plants were harvested at different times

Table 3 17

Chemical analysis of soils at three different experimental sites used for the amaranth experiments

Location	total N	P	Ca	Mg	K	Na
	%	ppm	cmol kg^{-1} soil			
Kukaiau	0 55 A	81 2 A	2 4 C	1 0 C	0 25 C	0 09 B
Iole	0 48 B	72 9 B	3 3 B	1 2 B	0 32 B	0 09 B
Waipio	0 18 C	78 3 AB	5 6 A	3 4 A	0 74 A	0 43 A

*Means in the same column with the same letters are not significantly different at 0 05 probability level (Waller-Duncan's multiple range test)

Table 3 18

Concentrations of some nutrients in soils at each experimental site of cassava and taro experiments

Site	cmol kg^{-1} soil				ppm
	Ca	Mg	K	Na	P
Molokai	4 6	2 0	1 3	0 20	20 2
Waipio	3 3	3 5	2 1	0 23	81 4
Iole	3 4	1 4	0 6	0 07	83 8
Kukaiau	2 6	0 9	0 4	0 07	110 1

Table 3 19

Soil chemical analysis results of irrigated and non-irrigated plots of three experimental sites

Site	Treatment*	Total N %	P ppm	Ca	Mg	K	Na
				cmol kg^{-1} soil			
Kukaiau	NI	0 54	74 3	2 4	0 9	0 23	0 08
	I	0 56	88 0	2 4	1 0	0 27	0 11
Significance level (F-test)		0 0016	0 0270	0 7231	0 4641	0 5386	0 1637
Iole	NI	0 45	75 6	4 0	1 4	0 32	0 11
	I	0 50	70 2	2 5	1 0	0 31	0 06
Significance level (F-test)		0 0003	0 1459	0 0001	0 0004	0 7053	0 1864
Waipio	NI	0 18	70 7	5 9	3 3	0 99	0 11
	I	0 17	85 9	5 3	3 5	0 49	0 77
Significance level (F-test)		0 2920	0 0426	0 0120	0 1597	0 0001	0 0001

*NI - non-irrigated
I = irrigated

Table 3 20

Weather characteristics during the growing period of amaranth grown at three sites

Site	Irrigation	Air temperature[a] (°C)			Soil temperature[a] (°C) Topsoil			Subsoil			Relative humidity[a] (%)			Cumulative rainfall[b] (mm)	Solar radiation[a] (Langley)	Wind speed[a] (km/hr)
		Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave			
Waipio	NI	27 3	15 7	21 5	21 1	20 4	20 8	21 9	21 7	21 8	78 7	45 6	62 2	115 6	768 2	7 2
	I	27 0	14 6	20 8	20 3	19 9	20 1	21 7	21 4	21 6	79 5	44 4	62 0	35 7	696 2	7 1
Iole	NI	22 9	13 2	18 1	18 8	18 1	18 5	20 4	20 1	20 3	90 0	55 6	72 8	332 0	363 6	4 1
	I	23 0	13 4	18 2	19 1	18 5	18 8	20 6	20 3	20 5	90 1	57 9	74 0	440 4	371 9	5 9
Kukaiau	NI & I	25 9	16 5	21 2	20 3	19 3	19 8	19 0	19 0	19 0	80 1	50 9	65 5	293 0	391 4	5 0

[a] Average daily values

[b] Cumulative values for the whole growing period

Table 3 21

Weather characteristics during the period from planting to sampling of cassava grown at four sites

Site	Air temperature[a] (°C)			Soil temperature[a] (°C) Topsoil			Soil temperature[a] (°C) Subsoil			Relative humidity[a] (%)			Cumulative rainfall[b] (mm)	Solar radiation[a] (Langley)	Wind speed[a] (km/hr)
	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave			
Molokai	28 7	20 5	24 6	21 5	21 1	21 3	22 0	21 8	21 9	97 8	71 0	84 4	441 9	510 0	19 0
Waipio	29 6	19 3	24 5	22 9	22 3	22 6	23 6	23 3	23 5	85 0	53 6	69 3	843 8	481 4	7 6
Iole	24 4	16 3	20 4	20 7	19 7	19 9	21 0	20 4	20 7	90 9	63 8	77 4	2354 8	351 9	9 8
Kukaiau	25 0	17 6	21 3	22 2	21 0	21 6	20 5	20 5	20 5	85 5	64 9	75 2	3088 6	370 7	8 1

[a]Average daily values

[b]Cumulative values from planting to sampling

Table 3 22

Weather characteristics during the period from planting to sampling of taro grown at three sites

Site	Air temperature[a] (°C)			Soil temperature[a] (°C)						Relative humidity[a] (%)			Cumulative rainfall[b] (mm)	Solar radiation[a] (Langley)	Wind speed[a] (km/hr)
				Topsoil			Subsoil								
	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave			
Waipio	31 2	19 9	25 6	23 8	23 2	23 5	24 4	24 0	24 2	84 1	51 8	68 0	585 0	533 5	6 9
Iole	24 8	16 6	20 7	20 9	20 4	20 7	21 7	21 5	21 6	90 7	64 9	77 8	1363 6	372 5	9 5
Kukaiau	25 9	18 6	22 2	23 3	22 0	22 7	21 3	21 3	21 3	85 3	65 8	75 5	1485 5	392 4	8 8

[a]Average daily values

[b]Cumulative values for the period from planting to sampling

CHAPTER IV

RESULTS AND DISCUSSION

The hypothesis to be tested is that the nutrient and antinutrient content and therefore the overall composition of food crops, are affected by controlled and uncontrolled environmental factors that regulate crop growth, development and performance This was tested by growing several test crops in a number of environmentally different sites The test crops were amaranth, taro and cassava with amaranth receiving the greatest attention Experimental sites were located on Oahu, Molokai, and two locations on the Big Island Hawaii The sites varied in temperature, moisture, and radiation regimes as well as in the chemistry and physics of the substrate The imposed treatments were fertilizer rates and water supply The aim of this study is to account for the expected variance in food composition and crop performance

The effect of both controlled and uncontrolled environmental factors on the number of days required for a crop of amaranth to mature differed among sites, and in some instances between treatments within sites It will become increasingly evident in this study that environmental factors other than those considered in this study contributed to variances in the dependent variables In the absence of insects weeds and pathogens water nutrients and energy supply are expected to affect crop performance If water nutrients and pests are controlled, energy supply in heat units becomes the major contributor to differences in growth and development Photoperiod can also affect crop performance, but in the amaranth experiment all plantings were completed within a two week period and the small latitudinal difference between Oahu and the Big Island of Hawaii was not expected to affect daylength

This chapter is written in two parts The first deals with the effect of controlled and uncontrolled environmental factors on crop growth, development, and performance of crops with emphasis on amaranth, and the second with the effect of environmental factors on the nutrient and antinutrient content of the same crops

4 1 Growth and development of amaranth

In evaluating the effects of controlled and uncontrolled environmental factors on amaranth, three crop-related parameters are considered which include (1) number of heat units required by amaranth to develop from planting to harvesting (2) dry weight of amaranth, and (3) moisture content of amaranth

4 1 1 Energy utilized by amaranth for emergence and growth

All things being equal the heat units required by plants of the same genotype to develop to a particular phenological stage should be the same In order to obtain information about the temperature requirement of amaranth in this study, heat units in degree days[1] were computed

[1]Heat unit (degree days)

$$\text{Heat unit/day} = \frac{T_{max} + T_{min}}{2} - T_{base}$$

for the period between planting and harvest of the plants (Table 4 1) With the exception of the Iole, irrigated and Waipio non-irrigated, the number of heat units required by the plants to reach harvest age after planting ranged from 581 to 769 degree days (Table 4 1) The higher cumulative heat units exhibited by Iole, irrigated plants are likely due to the uneven emergence and the late harvest of these plants The higher cumulative heat units exhibited by Waipio, non-irrigated plants are due to the delayed and uneven emergence resulting from lack of moisture

Disregarding the Waipio, non-irrigated and the Iole, irrigated treatments for the reason stated above, Iole plants took the longest chronological time to reach harvest age But in terms of heat units, or thermal time the Iole plants required nearly identical heat units to reach harvest age as did olants from Waipio This suggests that amaranth requires the same number of heat units to reach a particular phenological stage Because Iole occurs in a cooler environment it takes longer to accumulate the same amount of heat units According to a National Research Council report (1984), optimal germination temperatures of various accessions of amaranth varied between 16-35^{o}C The speed of seed emergence was increased at the upper end of this range Iole had the lowest minimum temperature of 13^{o}C (Table 3 20)

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where T_{max} = Maximum daily air temperature
T_{min} = Minimum daily air temperature
T_{base} = The lowest temperature whereby the metabolic functions and growth of plants ceases The temperature of 10^{o}C was used for amaranth
Heat unit for a period of plant development is the sum of heat units/day over that period

Table 4 1

Number of days and heat unit (degree days) from date of planting to harvest in the amaranth experiments

Growth duration	Treatment*	Site					
		Iole		Kukaiau		Waipio	
		Days	Degree days	Days	Degree days	Days	Degree days
Planting	NI	95	769	71	581	161	1942
to harvest	I	150	1255	71	581	70	757

* NI = Non-irrigated treatment, I = Irrigated treatment

The lower degree days recorded for the Kukaiau site can be attributed to the early harvest date Although every attempt was made to harvest each crop just before flowering, it was not possible to forecast flowering and to be on each island to await the proper harvest date

The fact that it took approximately 25 additional days in Iole non-irrigated treatment to accumulate the same number of heat units as in Waipio clearly indicates that the agroenvironments are different This difference is essential to test the hypothesis that nutrient contents of cultivar depends on the agroenvironment in which it is grown

4 1 2 Dry weight

Based on the concept of equal energy utilized by plants of the same genotype to develop to the same phenological stage, the dry weight comparisons are made on those that exhibited equal energy utilization (Table 4 1) These include the dry weight comparison between Iole, non-irrigated plants and Waipio, irrigated plants, and the comparison between Kukaiau, non-irrigated and irrigated plants

Table 4 2 shows that the plant dry weights from non-irrigated plots of Iole (90 5 g) and irrigated plots of Waipio (29 5 g) were significantly different This difference may be attributed almost totally to the difference in agroenvironment The moisture contents of these two groups of plants were similar as shown in Table 4 5 and, indicate that irrigation in Waipio compensated for natural rainfall in Iole As shown in Tables 4 24 and 4 25, total N concentration and uptake in Iole non-irrigated plants were significantly higher than those from Waipio irrigated plants This was likely because there was more N in the Iole soil than in that of Waipio soil (Table 3 17) This should be the main reason for higher dry weight in Iole

Higher dry weight from the non-irrigated than irrigated plants (Table 4 2) was also found by Varde (1984) for soybean and cabbage grown in Kukaiau Tables 4 23 and 4 25 show that uptake of cations anions and N was higher in plants from the non-irrigated plots than the irrigated ones

Phosphate fertilizer increased yields significantly in both non-irrigated and irrigated plants in Kukaiau and apparently also increased yields of non-irrigated plants at Iole (Table 4 3) These results confirm the notion that P is a limiting nutrient in Hydric Dystrandepts Application of N fertilizer increased the dry weight of Waipio irrigated plants significantly (Table 4 3) This shows that N was a major limiting nutrient in the Tropeptic Eutrustox The Benchmark Soils

Table 4 2

Effect of irrigation treatment on dry weight of amaranth

Treatment	Site		
	Kukaiau	Iole	Waipio
		(g/10 plants)	
Non-irrigated	65 3	90 5[a]	31 0
Irrigated	37 3	124 6	29 5[a]
Significance level (F-test)	0 0871	0 6864	0 8151

[a]The two means are significantly different at 0 05 probability level according to the least squares comparison

Project (1979) also demonstrated that P deficiency was frequently encountered in Hydric Dystrandepts while N was deficient in most cultivated Eutrustox due to its susceptability to leaching

Dry weight was not affected significantly by irrigation (Table 4 2) but the irrigation x fertilizer interaction was significant in Waipio plants (Appendix A) Significantly higher dry weight was found in N-treated Waipio, irrigated plants than in the N-treated non-irrigated, Waipio plants (Table 4 3 Figure 4 1) N and uptake of other nutrients in Waipio plants also showed this significant irrigation x fertilizer effects (Appendix A, Table 4 12) This indicates that providing adequate water is essential for proper growth and nutrient uptake in a dry site like Waipio

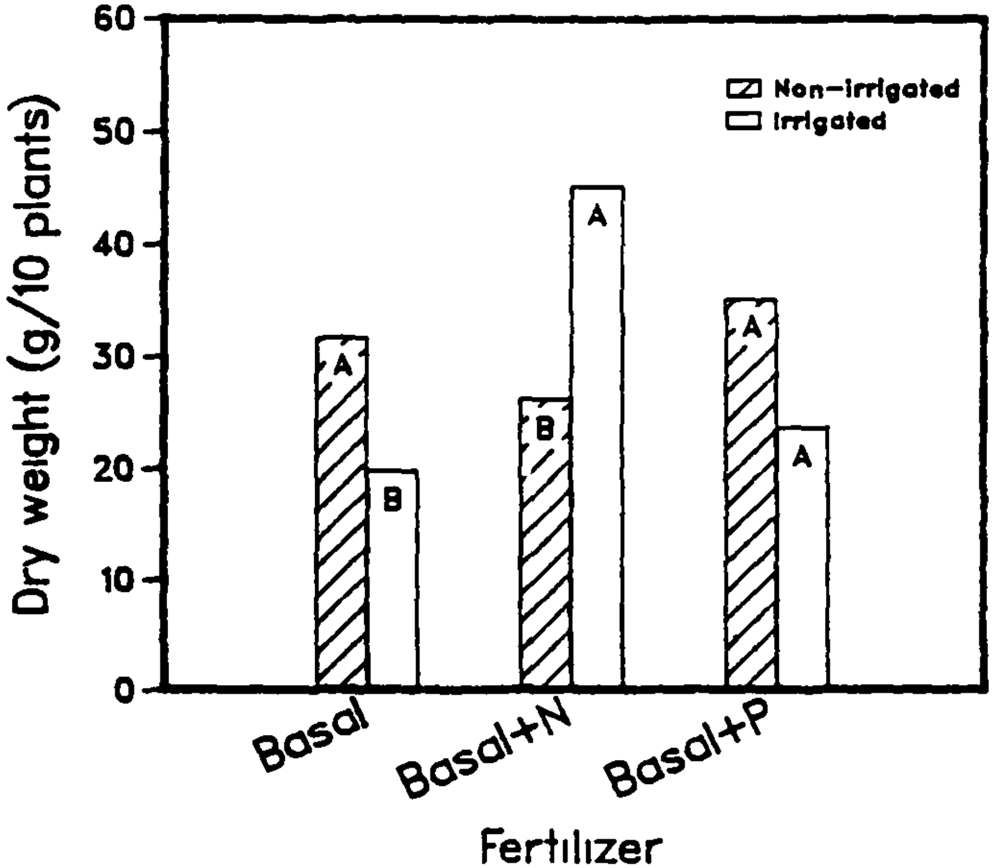
Table 4 3

Effects of fertilizer N and P on dry weights of amaranth in irrigated and non-irrigated plots at three sites

Fertilizer treatment	Dry weight (g/10 plants)					
	Kukaiau		Iole		Waipio	
	NI[a]	I[a]	NI[a]	I[a]	NI[a]	I[a]
Basal	35 4 Ba[b]	20 6 Ba[b]	67 5 Aa[b]	151 2 Aa[b]	31 7 Ab[b]	19 8 Ba[b]
Basal+N	46 1 Ba	23 1 ABa	59 9 Aa	165 3 Aa	26 2 Ab	45 1 Aa
Basal+P	114 5 Aa	68 2 Aa	144 0 Aa	70 9 Aa	35 1 Aa	23 6 Ba

[a]NI = Non-irrigated, I = Irrigated

[b]Means within the same location and irrigation treatment followed by the same capital letter are not significantly different at the 0 05 probability level Means within the same location and fertilizer treatment followed by the same small letter are not significantly different at 0 05 probability level according to the least squares pair comparison



Means of the same fertilizer treatment with the same letter are not significantly different at 0 05 probability level (Waller-Duncan's multiple range test)

Figure 4 1 Effect of irrigation x fertilizer interaction on dry weight of amaranth grown at Waipio site

4 1 3 Moisture content of plant tissue

The higher rainfall in Kukaiau and Iole led to significantly higher tissue moisture contents than those from Waipio (Table 4 4) Table 4 5 shows that in the Kukaiau and Iole sites irrigation did not increase tissue moisture content In Iole, however, the non-irrigated plants had significantly higher tissue moisture content than the irrigated plants These observations are not unexpected as Iole and Kukaiau receive sufficient rainfall during much of the year and irrigation may not be required or in some cases may depress plant growth through excess water If irrigation is to have sufficient beneficial effects, it would do so in Waipio where rainfall is infrequent The non-irrigated Waipio plants displayed their response to water stress by their small leaves and large proportion of stems (Table 3 3)

Table 4 4

Tissue moisture contents of amaranth grown at different sites

Site	Moisture content* (% fresh weight)
Kukaiau	89 7 A
Iole	87 1 B
Waipio	85 7 C

*Means followed by the same letter are not significantly different at 0 05 probability level (Waller-Duncan s multiple range test)

Table 4 5

Moisture content of amaranth grown at three different sites as affected by irrigation treatments

Site	Treatment[a]	Tissue moisture content (% fresh weight)
Kukaiau	NI	89 6
	I	89 9
Significance level (F-test)		0 6185
Iole	NI	88 9
	I	85 0
Significance level (F-test)		0 0014
Waipio	NI	81 4
	I	90 1
Significance level (F-test)		0 0001

[a]NI = Non-irrigated, I = Irrigated

4 2 Oxalate composition of amaranth tissue

4 2 1 Forms and amount of oxalate in amaranth

Two dominant fractions were found in amaranth These were the water soluble and water insoluble fractions Free oxalic acid (alcohol soluble fraction) could not be detected by the methods used in this study

In an attempt to identify the accompanying cation in each oxalate fraction correlations between the oxalate concentration of each fraction with its cations and with the cations in the plant tissue were determined (Table 4 6, Figures 4 2-4 5)

The high correlation between the concentrations of tissue K and K in the soluble oxalate fraction with the soluble oxalate, r=0 6392 and 0 6403, respectively (Table 4 6, Figure 4 2), suggested that K oxalate was the main form of soluble oxalate However, the higher correlation between the concentration of K plus Mg in the soluble oxalate fraction with the soluble oxalate, r=0 8558, suggested that Mg oxalate was an important part of the soluble oxalate (Figure 4 3)

Considering the insoluble oxalate fraction, the high and significant correlation between the concentrations of tissue Ca and Ca in the insoluble oxalate fraction with that of the insoluble oxalate (Table 4 6 Figure 4 4) shows that Ca oxalate was the main form of this fraction However, the improved correlation with Ca plus Mg was substituted for Ca (Figure 4 5) suggested that Mg oxalate was also an important constituent of the insoluble oxalate fraction In addition a portion of the Mg oxalate was probably extracted by hot water

Table 4 6

Correlation between soluble and insoluble fractions of oxalate with mineral composition of plant tissue and of fractionation extracts of amaranth

Mineral composition of tissue and fractions	Correlation coefficient* (Probability > |r|)	
	Soluble fraction of oxalate	Insoluble fraction of oxalate
Tissue K	0 6392 (0 0001)	-0 2146 (0 1346)
Ca	-0 3869 (0 0055)	0 6043 (0 0001)
" Mg	-0 0436 (0 7639)	-0 1528 (0 2896)
" Na	-0 0090 (0 9505)	-0 2031 (0 1571)
Soluble fraction K	0 6403 (0 0001)	-0 3465 (0 0128)
" ' Ca	-0 1689 (0 2360)	-0 1112 (0 4371)
" Mg	0 4087 (0 0029)	-0 3549 (0 0126)
' " Na	0 0287 (0 8413)	-0 2538 (0 0723)
" ' K + Mg	0 8558 (0 0001)	-0 5493 (0 0001)
Insoluble fraction K	-0 3240 (0 0204)	0 6980 (0 0001)
" " Ca	-0 3417 (0 0141)	0 6541 (0 0001)
" " Mg	-0 0930 (0 5161)	0 5227 (0 0001)
" Na	-0 1702 (0 2325)	0 3849 (0 0053)
" Ca + Mg	-0 3349 (0 0163)	0 7410 (0 0001)

*Number of observations = 54

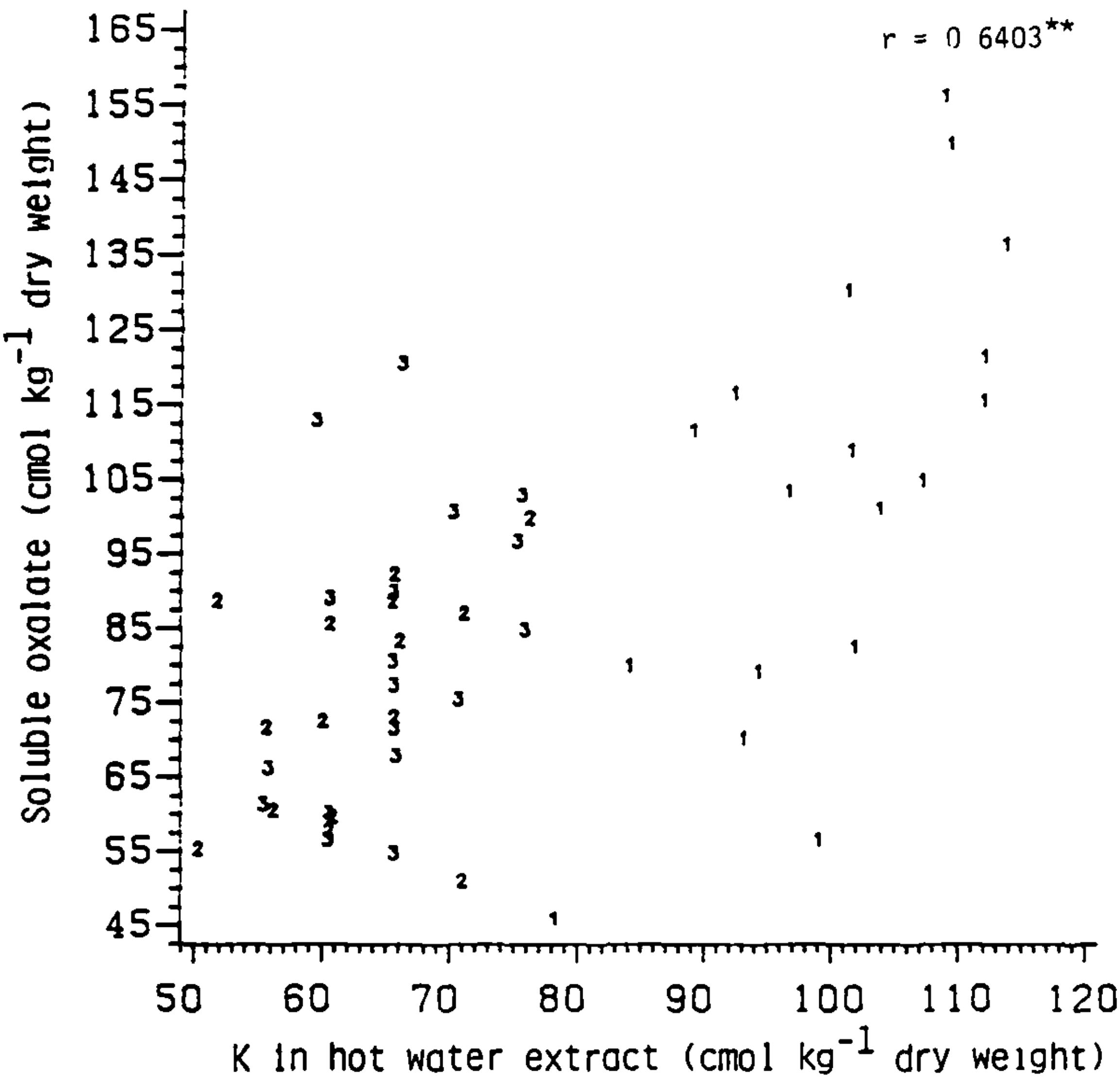


Figure 4 2 Relationship between soluble oxalate and K concentration in the extract of soluble oxalate fraction (hot water extract) of amaranth tissue
(1=Kukaiau, 2=Iole, 3=Waipio)

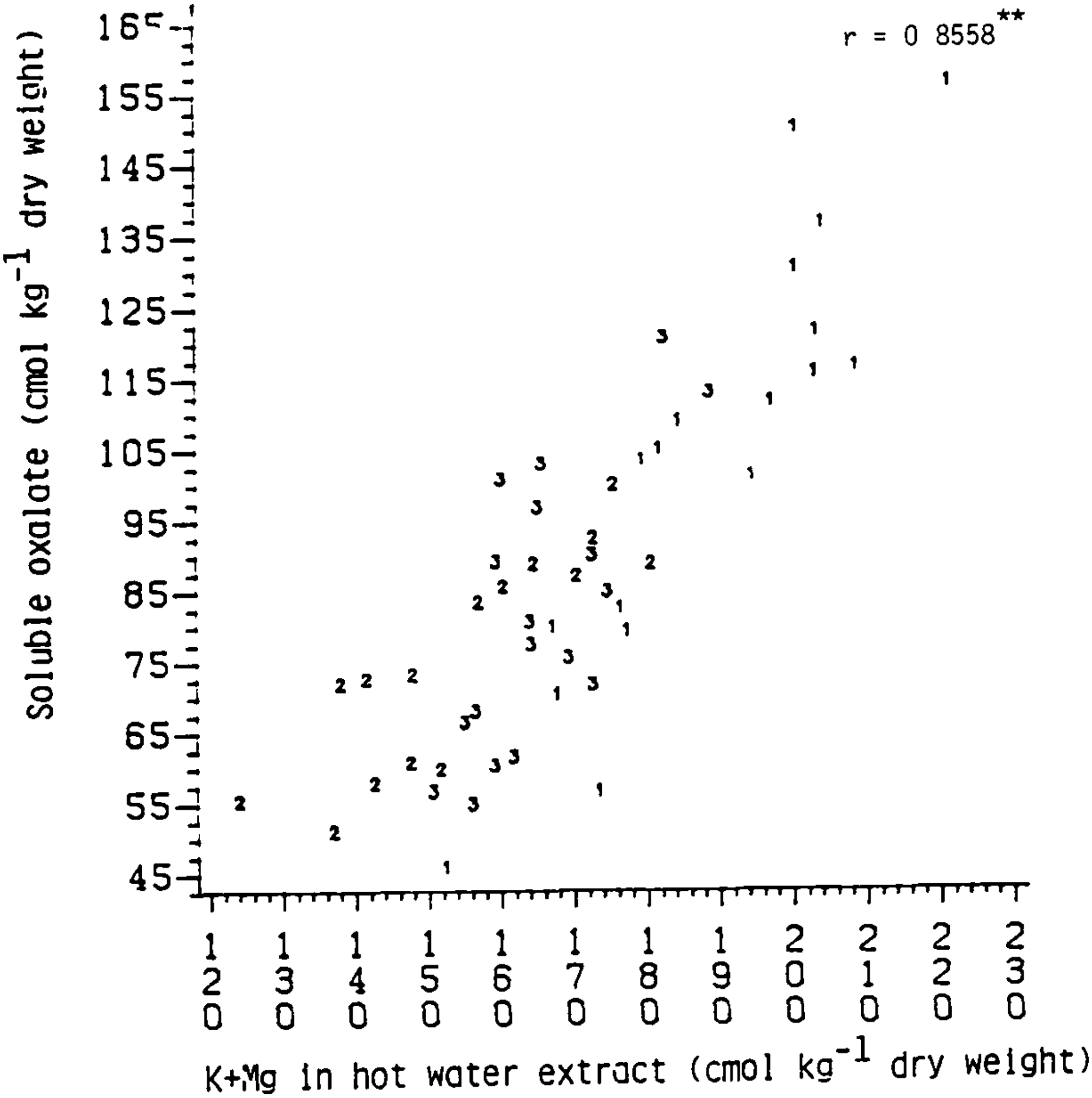


Figure 4 3 Relationship between soluble oxalate and the sum of potassium and magnesium concentration in the extract of soluble oxalate fraction (hot water extract) of amaranth tissue
(1=Kukaiau, 2=Iole, 3=Waipio)

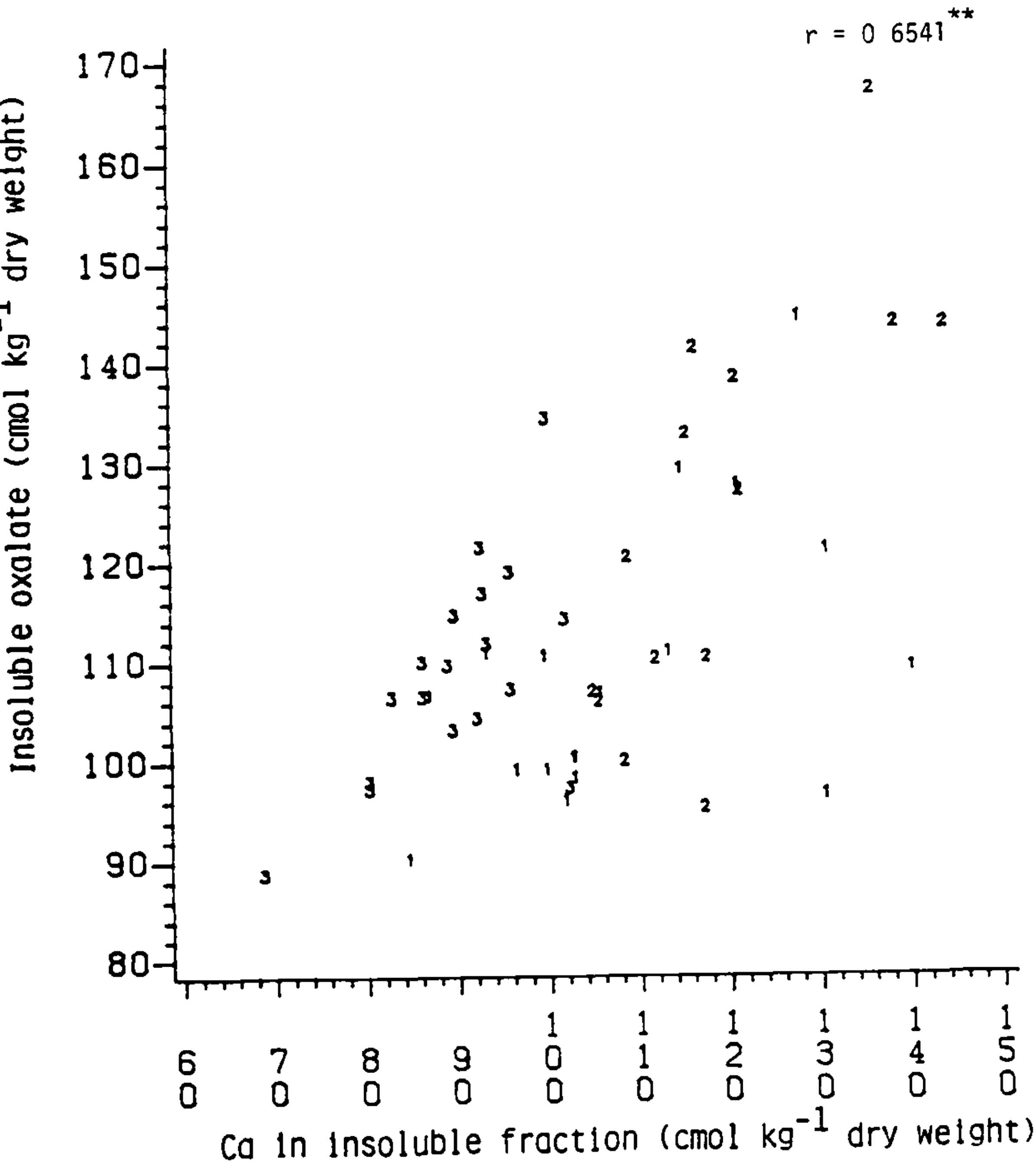


Figure 4 4 Relationship between insoluble oxalate and Ca concentration in the extract of insoluble oxalate fraction of amaranth tissue
(1=Kukaiau, 2=Iole, 3=Waipio)

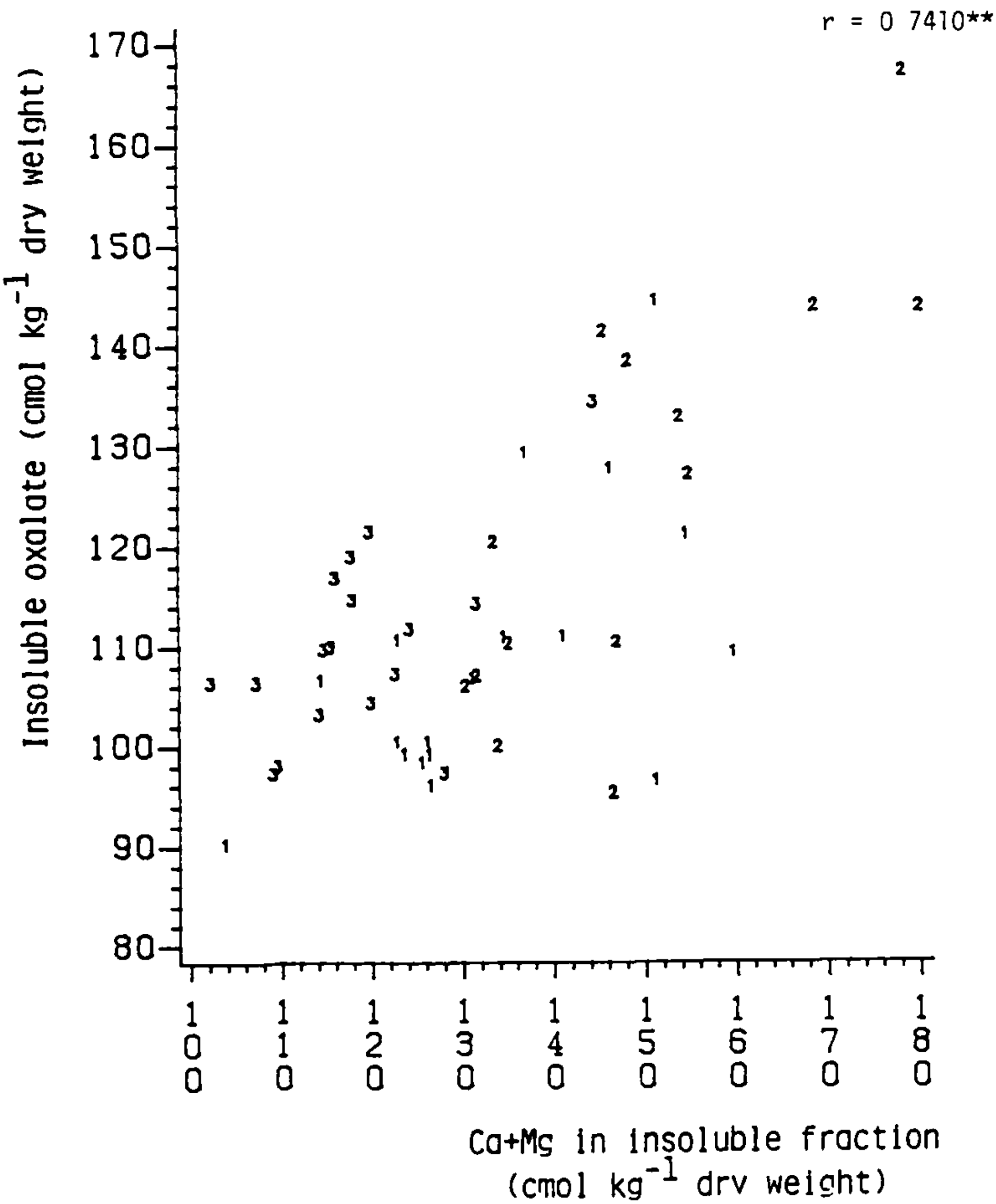


Figure 4 5 Relationship between insoluble oxalate and the sum of Ca and Mg concentration in the extract of insoluble oxalate fraction of amaranth tissue
(1=Kukaiau, 2=Iole, 3=Waipio)

The analysis of cations, including Ca, Mg, K and Na, in the soluble and insoluble fractions showed that the dominant cations in the soluble and insoluble fractions were respectively K and Ca (Table 4 7) There was relatively little K in the insoluble fraction extract and little Ca in the soluble fraction extract (Table 4 7) In Table 4 7, the sum of the cations must be greater than the oxalate concentration because other organic and inorganic anions were present in the extract

The concentration of soluble oxalate in plants from all three sites were nearly the same as that of K It is likely that the remainder of soluble oxalate was in the forms of Mg oxalate and Na oxalate The small amount of Ca found in this fraction was probably associated with water soluble salts, such as $CaCl_2$ (Table 4 7a)

Considering the insoluble fraction (Table 4 7b), the high Ca concentration which almost matched the concentration of insoluble oxalate was strong evidence that Ca oxalate was the dominant form in the insoluble fraction The remaining insoluble oxalate should be in the form of Mg oxalate The correlation between Mg in the insoluble fraction and insoluble oxalate was significant (Table 4 6)

Total oxalate in amaranth grown in Kukaiau was more than 9% It is interesting to note that higher concentrations of insoluble oxalate were found in amaranth grown in all sites (Table 4 8) Plants from Iole had 27% more insoluble oxalate than soluble oxalate, while Waipio plants had 14% and Kukaiau plants had 2% more

Two values of total oxalate were obtained in this study One was measured directly and the other was computed by adding the two

Table 4 7

Mineral concentrations in the (a) soluble, and (b) insoluble fractions of oxalate in amaranth from all plots in three sites

(a)

Site	Minerals and oxalate concentration (cmol kg^{-1} dry weight)						
	Oxalate	Ca	Mg	K	Na	SC*	Total cation - total oxalate
Kukaiau	104 0	0 9	88 6	100 0	4 6	194 1	90 1
Iole	75 2	0 8	91 6	62 5	3 7	158 6	83 4
Waipio	81 6	1 0	99 9	65 6	9 9	176 4	94 8

(b)

Site	Minerals and oxalate concentration (cmol kg^{-1} dry weight)						
	Oxalate	Ca	Mg	K	Na	SC*	Total cation - total oxalate
Kukaiau	108 7	108 5	24 7	2 3	1 4	136 9	28 2
Iole	128 2	120 4	30 5	3 4	1 4	155 7	27 5
Waipio	108 8	89 8	27 3	1 4	1 3	119 8	11 0

* Sum of cation concentration

Table 4 8

Relative concentrations of different fractions of oxalate produced in amaranth grown at three sites

Site	% dry weight				%	
	Total	Soluble+ insoluble	Soluble	Insoluble	Soluble	Insoluble
Kukaiau	9 2	4 7	9 6	4 9	49	51
Iole	8 4	9 2	3 4	5 8	37	63
Waipio	7 5	8 6	3 7	4 9	43	57

oxalate fractions Since the two values were significantly different (Table 4 9), the sum of the two fractions was used to obtain percent of any fraction relative to total oxalate

Table 4 9

Comparison of the two means of total oxalate of amaranth obtained by two different methods

Mean of total oxalate	Mean of soluble+insoluble oxalate
(cmol kg^{-1} dry weight)	
185 8	201 7

t-test = -2 9894

Probability > |t| = 0 0035

4 2 2 Oxalate and calcium concentrations in amaranth tissue

Figure 4 6 shows that the concentrations of insoluble oxalate and tissue Ca were very close This indicates that most Ca in amaranth tissue was bound in the form of Ca oxalate and was not available as a nutrient

4 2 3 Comparison of chemical composition in plants grown at different sites

Concentrations and productions of total soluble, insoluble and the combination of the soluble and insoluble oxalate were significantly different among the sites (Tables 4 10 and 4 11) Plants from Kukaiau had more total and soluble oxalate than those from Iole and Waipio On the other hand, plants in Iole had higher insoluble oxalate concentration than Kukaiau and Waipio plants (Table 4 10) Iole plants produced significantly higher quantities of all forms of oxalate than Kukaiau or Waipio plants (Table 4 11)

Table 4 10

Oxalate concentrations in amaranth grown at three sites

Site	Oxalate concentrations (cmol kg^{-1} dry weight)			
	Total*	Soluble*	Insoluble*	Soluble + insoluble*
Kukaiau	204 3 A	104 0 A	108 7 B	212 7 A
Iole	186 9 B	75 2 B	128 2 A	203 4 A
Waipio	166 3 C	81 6 B	108 8 B	190 4 B

* Means in the same column followed by the same letter are not significantly different at 0 05 probability level (Waller-Duncan s multiple range test)

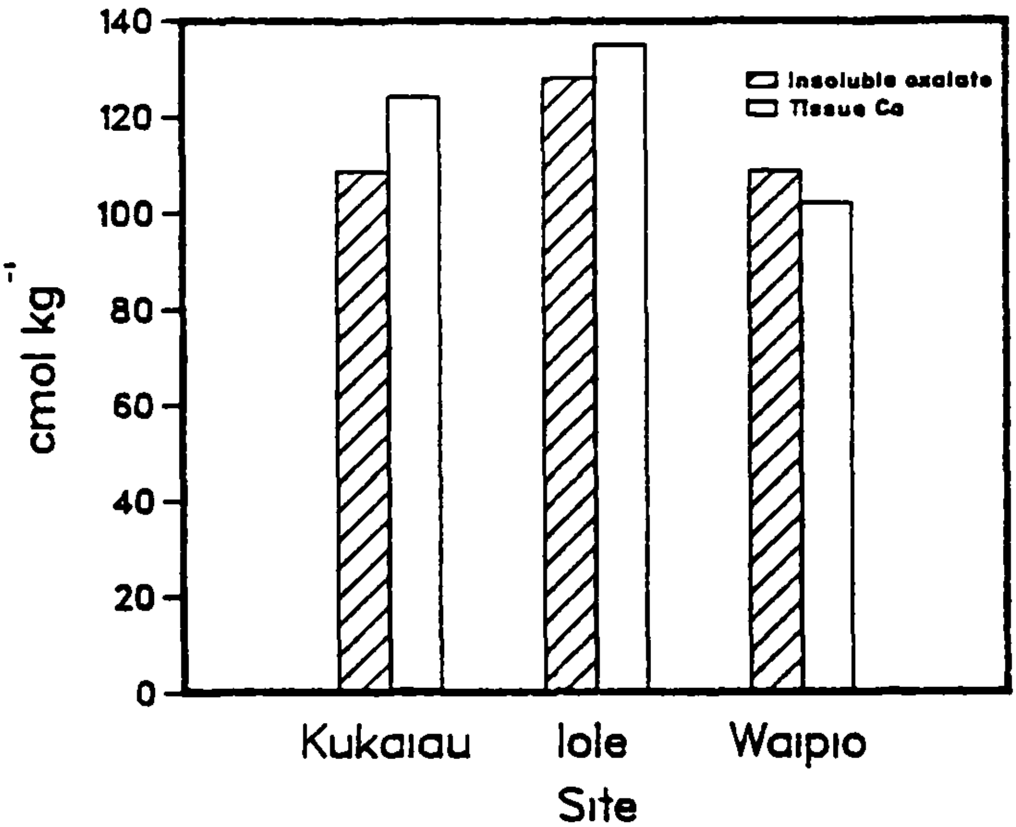


Figure 4 6 Comparative concentration of insoluble oxalate and tissue Ca in amaranth growth at three sites

Table 4 11

Oxalate production in amaranth grown at three different sites

Site	Oxalate production (g/10 plants)			
	Total*	Soluble*	Insoluble*	Soluble + insoluble*
Kukaiau	4 6 B	2 0 B	2 7 B	4 7 B
Iole	9 8 A	3 7 A	7 0 A	10 8 A
Waipio	2 3 B	1 1 B	1 5 B	2 6 B

*Means in the same column followed by the same letter are not significantly different at 0 05 probability level (Waller-Duncan's multiple range test)

Ionic and total N concentrations in plant tissue are thought to be factors affecting the oxalate concentrations in plants Kukaiau and Iole plants had higher tissue ionic concentrations and uptake values than Waipio plants (Tables 4 12 and 4 13) They also had higher total N concentration and uptake than Waipio plants (Tables 4 18 and 4 19) Schmidt et al (1971) reported that Amaranth species which were grown on soils with high soil carbon, nitrogen available phosphorus and potassium contents produced higher total oxalate relative to those grown on less fertile soils Although the Kukaiau and Iole soils were less fertile than the Waipio soil with respect to base status they had higher nitrogen contents than the Waipio soil Consequently plants from Kukaiau and Iole had higher concentrations and uptake of various ions than those from Waipio More importantly, Kukaiau and Iole plants had higher cation excess than Waipio plants (Table 4 12) According

Table 4 12

Ionic concentrations and cation excess contents of amaranth grown at three sites

Site	Ca	Mg	K	Na	SC**	P	S	NO_3	Cl	SA***	C-A
	----------	----------	----------	----------	cmol kg^{-1} dry weight	----------	----------	----------	----------	----------	----------
Kukaiau	124 4 B*	99 3 C*	147 6 A*	5 0 B*	376 1 A*	3 4 A*	8 3 C*	31 1 A*	7 1 B*	49 9	326 3 A*
	(2 49)	(1 19)	(5 77)	(11)		(33)	(40)	(1 92)	(25)		
Iole	135 1 A	118 4 A	117 9 B	4 9 B	376 3 A	2 6 B	10 1 A	23 4 B	6 9 B	43 0	333 3 A
	(2 70)	(1 42)	(4 61)	(11)		(25)	(49)	(1 45)	(24)		
Waipio	102 2 C	112 4 B	108 2 C	8 5 A	331 4 B	3 1 A	9 3 B	9 6 C	7 6 A	29 6	301 7 B
	(2 04)	(1 34)	(4 23)	(11)		(30)	(45)	(60)	(27)		

* Means in the same column followed by the same letter are not significantly different at 0 05 level of probability (Waller-Duncan's multiple range test)

** Sum of cation concentration

*** Sum of anion concentration

Table 4 13

Ionic uptake by amaranth grown at three sites

Site	Ca	Mg	K	Na	P	S	NO_3	Cl
	---------------------------g/ 10 plants							--
Kukaiau	1 4 B*	0 6 B*	2 9 B*	0 06 B*	0 17 B*	0 23 B*	0 95 A*	0 14 B*
Iole	3 4 A	1 5 A	5 0 A	0 10 A	0 27 A	0 53 A	1 44 A	0 27 A
Waipio	0 6 B	0 4 B	1 3 B	0 06 B	0 09 B	0 14 B	0 18 B	0 08 B

* Means in the same column followed by the same letter are not significantly different, at 0 05 level of probability (Waller-Duncan s multiple range test)

to the cation-anion balance concept, organic acids including oxalate are synthesized to balance excess cations

The significantly higher soluble oxalate concentration in Kukaiau plants (Table 4 10) was probably due to the higher equivalent concentration of tissue K in these plants compared with Iole and Waipio plants (Table 4 12) In the previous section (4 2 1) it was concluded that soluble oxalate was primarily K oxalate

Higher concentration and production of insoluble oxalate in plants grown in Iole relative to Kukaiau and Waipio plants (Tables 4 10 4 11) may be attributed to the higher Ca and Mg concentrations of Iole (Table 4 12)

Soluble oxalate concentrations of Iole and Waipio plants were significantly different when only irrigated plants were considered (Table 4 14) This showed that when the variance due to irrigation effect was removed, the significant site effect emerged The concentration of the sum of soluble and insoluble oxalate of the plants from Kukaiau and Iole were significantly different when only non-irrigated plants were considered as shown in Table 4 15

The plants from Waipio, irrigated plots also had higher tissue K, Mg and Na but lower Ca concentration than those from Iole (Table 4 22) This was in accordance with the higher soluble oxalate in Waipio irrigated plants than Iole plants

It appears from these findings that the amount and distributions of the various oxalate fractions were determined to a certain extent by the type and amount of cations in amaranth tissue In plants from Iole, Ca was the dominant cation (Table 4 12) and insoluble oxalate

Table 4 14

Soluble oxalate concentration of amaranth grown in irrigated experiments of Iole and Waipio

Site	Soluble oxalate (cmol kg^{-1} dry weight)
Iole	68 5
Waipio	85 0
Significance level (LSD)	0 0460

Table 4 15

Concentration of the sum of soluble and insoluble oxalate of amaranth grown in non-irrigated experiments of Kukaiau and Iole

Site	Soluble+insoluble oxalate (cmol kg^{-1} dry weight)
Kukaiau	212 2
Iole	191 0
Significance level (LSD)	0 0090

was the principal form of oxalate (Table 4 10) On the other hand, K was the dominant cation in Kukaiau plants (Table 4 12), but there was no significant difference between the concentrations of soluble and insoluble oxalate (Table 4 10) The Waipio plants had approximately equal concentrations of K and Ca (Table 4 12), but insoluble oxalate was the dominant form of oxalate (Table 4 10) This last result together with that from Kukaiau seemed to suggest that amaranth tended to synthesize Ca oxalate in preference to K oxalate

Factors which affect ionic uptake by plants influence the kind and amount of oxalate produced by plants (Tables 4 10, 4 12) The plants grown in the high base, low N, Tropeptic Eutrustox did not have as high concentrations of bases in their tissue as those grown in the low base, high N Hydric Dystrandepts This indicates that without adequate N, plants cannot make use of available resources, such as bases or phosphorus

<u>Ionic concentrations and uptake of plants grown at different sites</u>

The Hydric Dystrandept in Iole appeared to be richer in Ca Mg and K than the soil at Kukaiau (Table 3 17) This contributed to the higher concentrations of Ca and Mg in plants from Iole than in those from Kukaiau (Table 4 12) However the significantly higher K concentration in the Kukaiau plants than in the Iole plants in spite of the higher K concentration in the Iole soil (Table 3 17) may be due to dilution from higher biomass production in Iole

It is likely that the significantly higher Na concentration in Waipio plants relative to Kukaiau and Iole plants was due to a high

Na concentration in the irrigation water This was also true for Cl concentration (Table 4 12)

With the exception of Na, the higher cation and anion uptake by Kukaiau and Iole plants relative to Waipio plants (Table 4 13) was likely due to the higher biomass and plant demand of Kukaiau and Iole plants than Waipio plants Earlier studies have shown that ion uptake is closely related to plant growth and to the supply of sugar and metabolites translocated from the shoot to the root (Pitman, 1972, White 1973)

Relationship between oxalate concentrations and cation excess content

Total oxalate from all sites exhibited significant correlation with cation excess (Table 4 16, Figure 4 7) However when the relationship was analyzed locationwise, only Waipio plants exhibited high and significant correlation between total oxalate and (C-A) (Table 4 16, Figure 4 8) The same situation was applicable to soluble+insoluble oxalate (Table 4 16, Figures 4 9 4 10) Significant correlations although not considered high, were also found between soluble oxalate and (C-A) in Waipio, and insoluble oxalate and (C-A) in Kukaiau (Table 4 16)

The results in Table 4 17 suggest that about 60% of the cation excess in amaranth grown at the three sites was balanced by oxalate

Total N and nitrate-N concentrations and uptake and crude protein contents

Total N concentration and uptake were significantly higher in Kukaiau and Iole plants than those from Waipio (Tables 4 18 and 4 19)

Table 4 16

Correlation between concentrations of different oxalate forms and cation excess

Oxalate	Correlation coefficient (Probability > |r|)			
	Combined[a] sites	Kukaiau[b]	Iole[b]	Waipio[b]
Total	0 3916	-0 3441	0 3158	0 6156
	(0 0045)	(0 1620)	(0 2515)	(0 0065)
Soluble	-0 0108	-0 3697	0 0940	0 4815
	(0 9405)	(0 1311)	(0 7494)	(0 0431)
Insoluble	0 4793	0 5229	0 3619	0 3905
	(0 0004)	(0 0206)	(0 2036)	(0 1091)
Soluble +	0 3442	-0 1751	0 4146	0 5790
insoluble	(0 0144)	(0 4871)	(0 1405)	(0 0118)

[a]Number of observations = 54

[b]Number of observations = 18

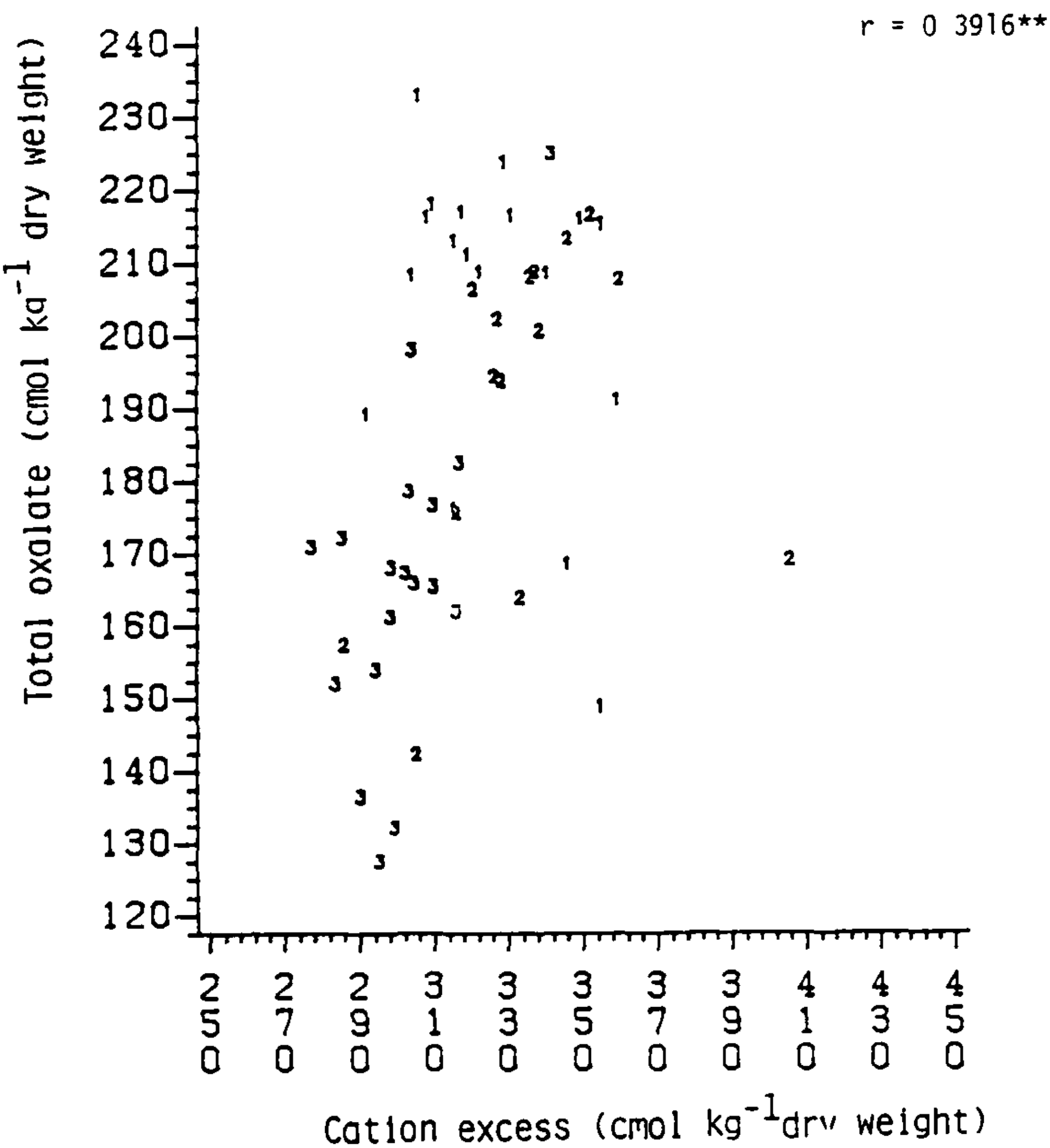


Figure 4 7 Relationship between total oxalate and cation excess in amaranth from all plots of the experiments at three sites
(1-Kukaiau, 2=Iole, 3=Waipio)

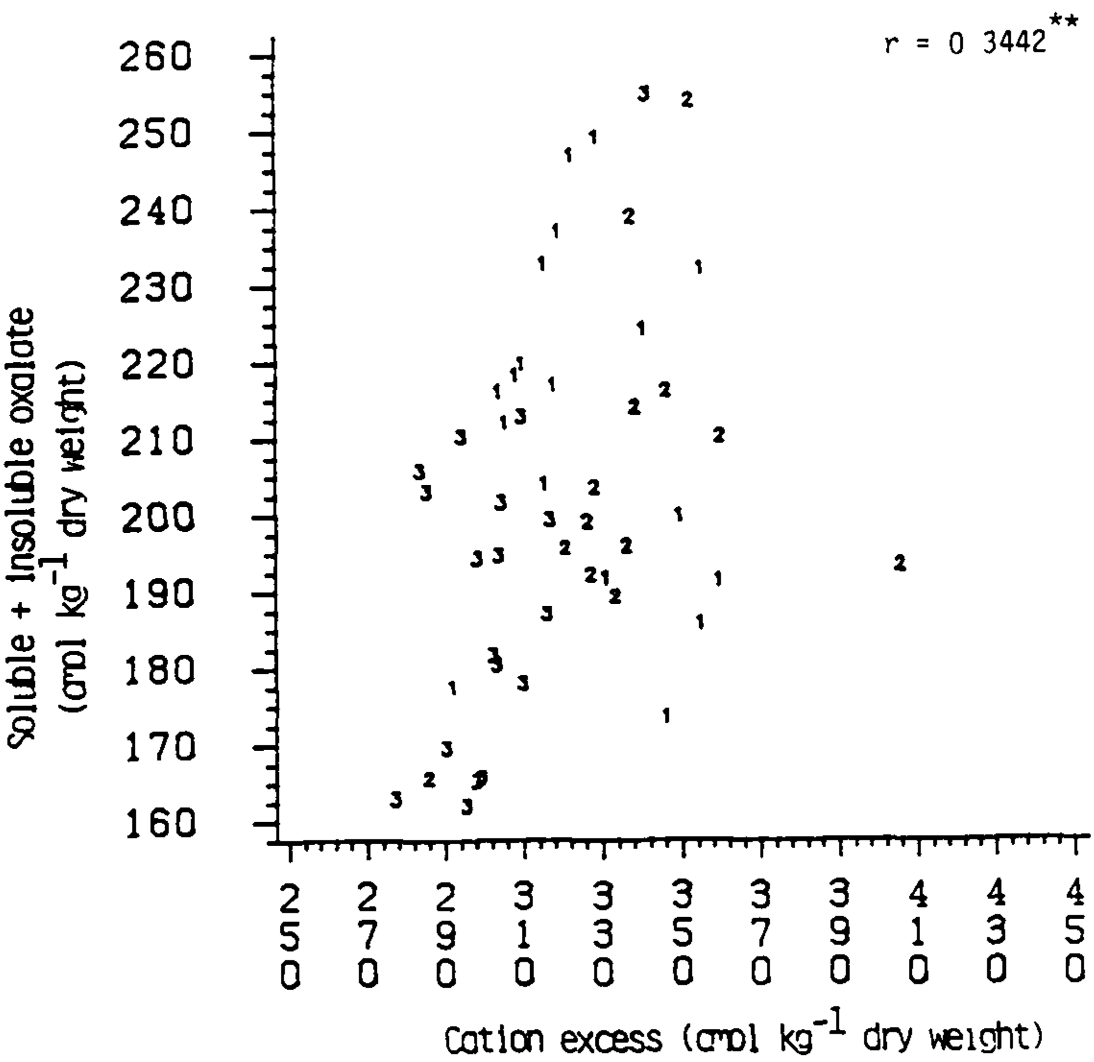


Figure 4 8 Relationship between the sum of soluble and insoluble oxalate and cation excess in amaranth from all plots of the experiments at three sites (1=Kukaiau, 2=Iole, 3=Waipio)

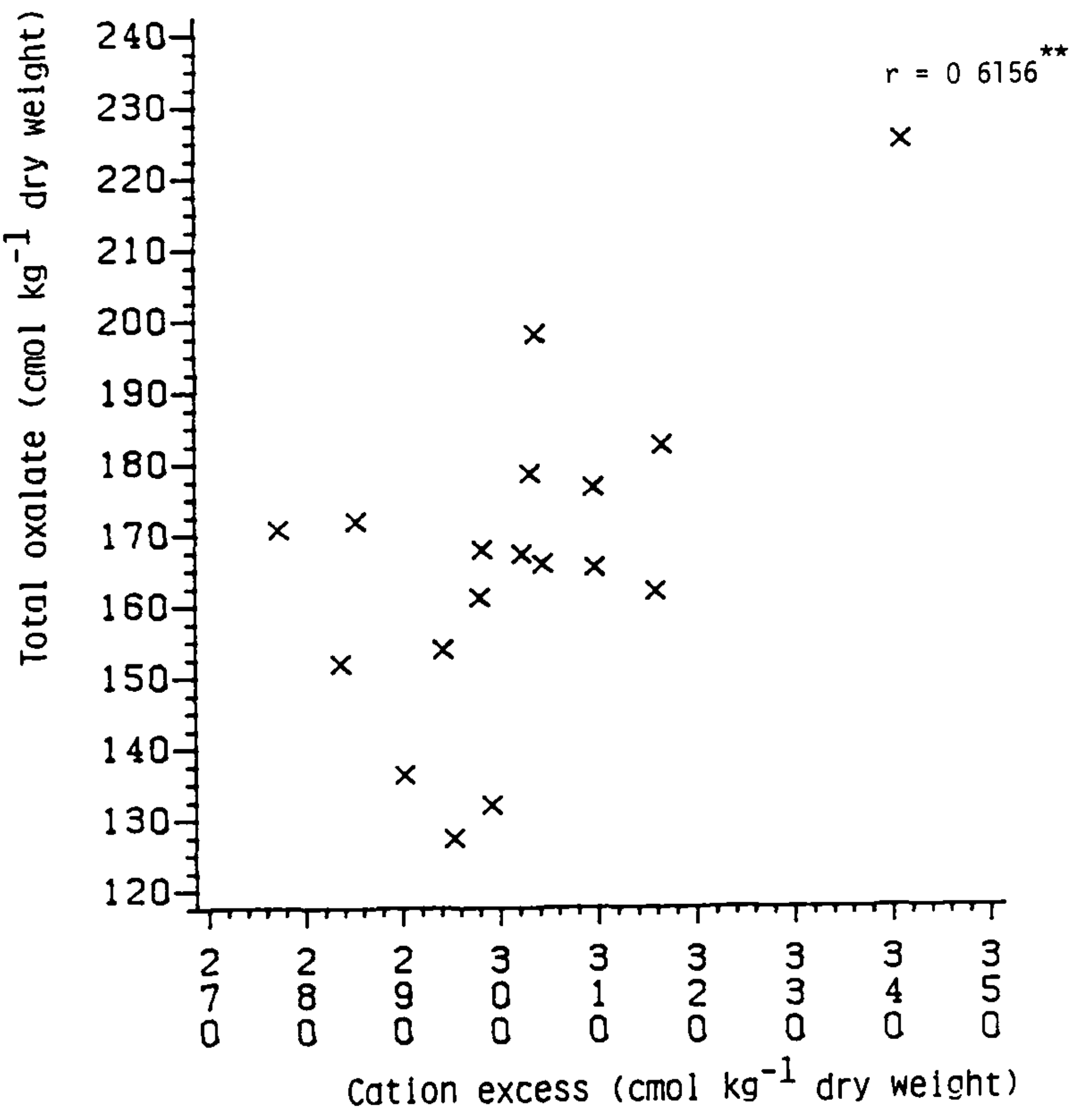


Figure 4 9 Relationship between total oxalate and cation excess in amaranth from Waipio site

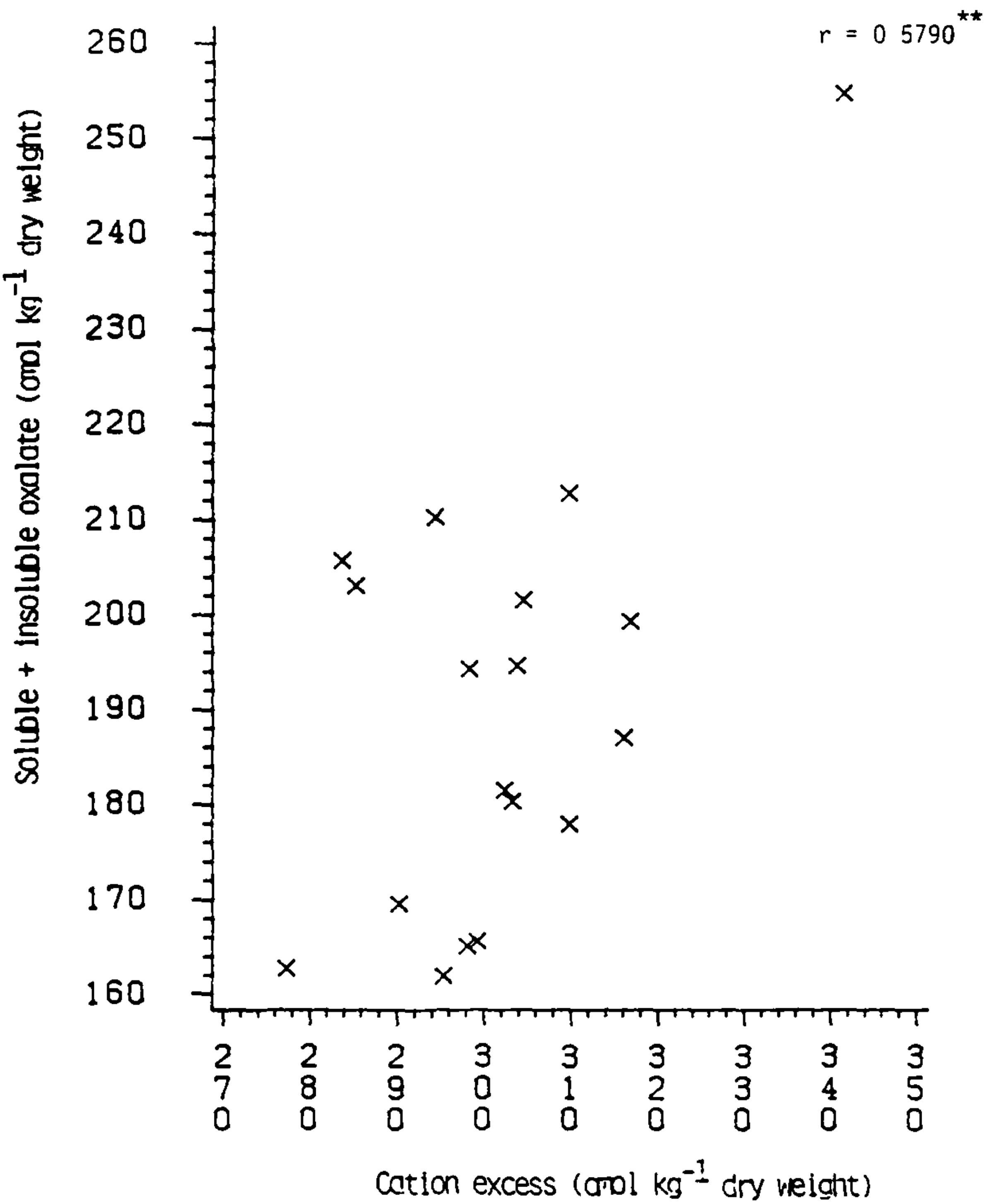


Figure 4 10 Relationship between the sum of soluble and insoluble oxalate and cation excess in amaranth from Waipio site

Table 4 17

Proportion of total oxalate and the sum of soluble and insoluble oxalate relative to cation excess (C-A)

Site	(C-A) (cmol kg^{-1})	Total oxalate		Soluble+insoluble oxalate	
		Conc (cmol kg^{-1})	% (C-A)	Conc (cmol kg^{-1})	% (C-A)
Kukaiau	326 3	204 3	62 6	212 7	65 2
Iole	333 3	186 9	56 1	203 4	61 0
Waipio	301 7	166 3	55 1	190 4	63 1

Table 4 18

Total N, nitrate-N concentration and crude protein content of amaranth grown at three sites

Site	Total N*	Nitrate-N*	Crude protein*
	% dry weight		
Kukaiau	4 53 A	0 52 A	28 3 A
Iole	4 28 B	0 33 B	26 8 B
Waipio	3 28 C	0 13 C	20 5 C

* Means in the same column followed by the same letter are not significantly different at 0 05 probability level (Waller-Duncan s multiple range test)

Table 4 19

Total N and nitrate-N uptake by amaranth grown at three sites

Site	Total N*	Nitrate-N*
	------------ g/10 plants -----------	
Iole	4 77 A	1 44 A
Kukaiau	2 24 B	0 95 A
Waipio	0 99 B	0 18 B

* Means in the same column followed by the same letter are not significantly different at 0 05 probability level (Waller-Duncan's multiple range test)

and this is related to soil nitrogen levels When the tissue total N values were converted to crude protein (on a dry weight basis), they were comparable to the values of 27-33% reported by the National Research Council (1984) for four species of amaranth However, the crude protein of Waipio plants was lower relfecting the low N content of the Tropeptic Eutrustox

The higher total N uptake in Kukaiau and Iole plants (Table 4 19) reflected larger biomass production at Kukaiau and Iole Even though the Waipio plants especially the irrigated ones, had the advantage of higher solar radiation and temperature relative to Kukaiau and Iole plants, low N prevented higher yields from being achieved in Waipio When soil N is deficient growth rate is low and plant nutrient demand is also low consequently the uptake of other nutrients becomes low also, although they are available White (1973) has pointed out that P uptake depends on the relative growth rate and on environmental factors, including the supply of other essential nutrients, such as nitrogen

The nitrate-N content of amaranth grown in Kukaiau and Iole (Table 4 18) were comparable to the content of nitrate-N in various varieties of Amaranthus gangeticus L (0 3-0 9% on a dry weight basis) reported by Der Marderosian et al (1981) However, the nitrate-N content in Waipio plants was unusually low only 0 13% (Table 4 18) This is additional evidence that the N content of the Waipio soil was too low to support the normal growth of plants Nitrate accumulation is regarded as a natural and necessary process in plants and attempts to reduce nitrate accumulation can result in yield reduction (Lorenz, 1978)

Whether nitrate concentration found in amaranth in this study was potentially toxic depends on the amount of fresh vegetable consumed Given a moisture content of 90% and a nitrate-N content on a dry weight basis of 0 5% (e g , the content in amaranth grown in Kukaiau, Table 4 18), the nitrate-N on a fresh weight basis would be 0 05% According to Gilbert et al (1946) 0 5 g is a toxic daily dose Thus approximately 1000 g of fresh amaranth would need to be consumed each day to attain toxic levels of nitrate-N intake Der Marderosian et al (1981) did not think that more than 100 g fresh green vegetables would be consumed in a day Their argument was probably based on an American diet The recommended quantity of vegetable diets for various groups of people in Africa is 150 g (Latham 1979) Therefore it appears that the nitrate-N content in amaranth will not be a health hazard unless an unlikely large quantity of this vegetable is consumed fresh

When green vegetables are cooked especially by boiling or blanching, a large part of nitrate is dissolved in cooking water Vegetables prepared this way will have less nitrate-N content, and less potential health hazard

4 2 4 <u>Effect of irrigation on plant chemical composition</u>

The uneven performance of amaranth did not permit the effect of irrigation to be interpreted clearly As pointed out in Chapter III the irrigated plots at each experimental site were treated as if irrigation was the main plot of a split-plot design when in fact it was not Thus the irrigation effect should be interpreted with this in mind In addition, the Kukaiau and Iole sites are naturally wet and, consequently, irrigation would not necessarily result in different plant performance This is reflected in moisture contents of amaranth from Kukaiau and Iole as shown in Table 4 5

On the other hand, Waipio is a dry site and hence, the irrigation effect was anticipated to be greater However, the effect of irrigation there was confounded by the fact that the non-irrigated and irrigated crops were harvested at different times which resulted in their being exposed to different weather This was also true for the Iole, non-irrigated and irrigated plants where the irrigated crop was left in the field for a much longer period

The significantly higher insoluble oxalate content in Iole irrigated amaranth relative to the non-irrigated treatment as shown in Table 4 20 went hand in hand with the higher Ca concentration in the amaranth from the irrigated plots (Table 4 22) This difference

Table 4 20

Effect of irrigation on oxalate concentration of amaranth grown at three sites

Oxalate	Irrigation treatment	(cmol kg^{-1} dry weight)		
		Kukaiau	Iole	Waipio
Total	non-irrigated	201 3	190 5	169 0
	Irrigated	207 4	182 2	163 6
Significance level (F-test)		0 5889	0 4755	0 4722
Soluble	Non-irrigated	99 0	78 4	78 2
	Irrigated	108 9	70 4	85 0
Significance level (F-test)		0 4009	0 3383	0 5060
Insoluble	Non-irrigated	113 2	112 7	110 4
	Irrigated	104 2	151 6	107 2
Significance level (F-test)		0 0727	0 0235	0 5155
Soluble+Insoluble	Non-irrigated	212 2	191 0	188 6
	Irrigated	213 1	221 9	192 2
Significance level (F-test)		0 9379	0 2476	0 7107

in insoluble oxalate content was most likely due to the difference in age and harvest time

The higher concentration of soluble oxalate in irrigated than the non-irrigated amaranth from Kukaiau (Table 4 20) appears to be associated with the higher K concentration in the irrigated plants (Table 4 22) On the other hand, soluble oxalate production and K uptake were lower in the irrigated Kukaiau plants than in the non-irrigated ones (Tables 4 21, 4 23) This suggests that the lower concentration of soluble oxalate in the non-irrigated amaranth relative to the irrigated ones was primarily due to dilution from high dry matter yield (Table 4 2)

Significant differences in Ca and P contents of plants from the irrigated and non-irrigated plots were observed (Table 4 22) These differences may be the consequence of factors other than the irrigation treatment The significantly higher Ca concentration in irrigated Iole plants, and non-irrigated Waipio plants than their counterparts may be simply due to lower Ca in the counterpart soil (Table 3 17) The same argument can be applied to the higher P content in irrigated Waipio plants than the non-irrigated ones (Table 4 22)

Significantly higher Na and Cl concentrations in Waipio irrigated plants relative to the non-irrigated ones was probably due to the high Na and Cl in the irrigation water

Irrigation had significant effects on total N and nitrate-N concentrations only in Iole plants (Table 4 24) There are reasons to believe that this difference is not due to irrigation It should be recalled that the irrigated plants in Iole emerged unevenly and at a

Table 4 21

Effects of irrigation on the production of oxalates in amaranth grown at three sites

Oxalate	Irrigation treatment	g/10 plants		
		Kukaiau	Iole	Waipio
Total	Non-irrigated	5 7	7 6[a]	2 4
	Irrigated	3 5	12 6	2 2[a]
Significance level (F-test)		0 1402	0 3417	0 7688
Soluble	Non-irrigated	2 5	3 0[b]	1 09
	Irrigated	1 6	4 9	1 13[b]
Significance level (F-test)		0 1373	0 5850	0 8228
Insoluble	Non-irrigated	3 6	4 6[c]	1 54
	Irrigated	1 8	10 7	1 48[c]
Significance level (F-test)		0 0536	0 3996	0 8401
Soluble + insoluble	Non-irrigated	6 0	7 6[d]	2 63
	Irrigated	3 4	15 5	2 61[d]
Significant level (F-test)		0 0764	0 4506	0 9652

a The two means are significantly different at 0 0436 probability level (LSD test)

b c d The two means are significantly different at 0 01 probability level (LSD test)

Table 4 22

Effect of irrigation on ionic concentration of amaranth grown at three sites

Site	Irrigation*	cmol kg^{-1} dry weight (% dry weight)							
		Ca	Mg	K	Na	P	S	NO_3	Cl
Kukaiau	NI	125 9 (2 59)	101 3 (1 22)	144 5 (5 64)	5 0 (0 11)	3 1 (0 30)	8 7 (0 42)	7 6 (0 47)	7 2 (0 26)
	I	122 8 (2 45)	97 4 (1 17)	150 7 (5 89)	5 1 (0 12)	3 7 (0 36)	7 9 (0 38)	6 4 (0 40)	6 9 (0 24)
Probability > |F|		0 7961	0 5778	0 0017	0 7846	0 3786	0 2334	0 2088	0 4570
Iole	NI	126 5 (2 53)	119 4 (1 43)	126 1 (4 93)	5 2 (0 12)	2 7 (0 26)	9 9 (0 48)	6 9 (0 43)	6 8 (0 24)
	I	146 2 (2 92)	117 1 (1 41)	107 3 (4 19)	4 5 (0 10)	2 6 (0 25)	10 3 (0 50)	3 2 (0 20)	7 0 (0 25)
Probability > |F|		0 0445	0 7897	0 0222	0 0295	0 0454	0 4009	0 0222	0 5493
Waipio	NI	109 6 (2 19)	100 7 (1 21)	106 6 (4 16)	4 7 (0 11)	1 9 (0 18)	9 0 (0 43)	2 2 (0 14)	7 0 (0 25)
	I	94 8 (1 90)	124 1 (1 49)	109 9 (4 29)	12 4 (0 29)	4 5 (0 44)	9 7 (0 47)	2 2 (0 14)	8 3 (0 29)
Probability > |F|		0 0055	0 0176	0 4955	0 0001	0 0001	0 0184	0 9702	0 0033

* NI = Non-irrigated   I = Irrigated

Table 4 23

Effect of irrigation on ion uptake by amaranth grown at three sites

Site	Irrigation*	g/10 plants							
		Ca	Mg	K	Na	P	S	NO_3	Cl
Kukaiau	NI	1 76	0 78	3 62	0 08	0 21	0 30	1 26	0 18
	I	1 02	0 42	2 18	0 04	0 14	0 15	0 65	0 10
Probability > |F|		0 1244	0 0523	0 1218	0 0885	0 1578	0 0611	0 1138	0 0917
Iole	NI	2 33	1 25	4 44	0 11	0 26	0 44	1 51	0 23
	I	4 86	1 87	5 70	0 13	0 28	0 64	1 36	0 33
Probability > |F|		0 2888	0 5218	0 6999	0 7507	0 9774	0 5609	0 7761	0 5596
Waipio	NI	0 68	0 38	1 28	0 03	0 06	0 13	0 19	0 08
	I	0 58	0 43	1 30	0 08	0 12	0 14	0 18	0 09
Probability > |F|		0 4404	0 4848	0 9677	0 0261	0 0444	0 8752	0 9738	0 6504

* NI - Non-irrigated   I = Irrigated

Table 4 24

Effect of irrigation on total N and nitrate-N concentration in amaranth grown at three sites

Irrigation	Kukaiau		Iole		Waipio	
	Total N	NO_3-N	Total N	NO_3-N	Total N	NO_3-N
	(% dry weight)					
Non-irrigated	4 52	0 47	4 68[a]	0 43[b]	3 15	0 14
Irrigated	4 55	0 40	3 77	0 20	3 41[a]	0 13[b]
Probability > |F|	0 8453	0 2088	0 0167	0 0222	0 3363	0 9702

a, b The two means superscripted by the same small letter are significantly different at 0 0001 probability level (LSD test)

much slower rate This fact coupled with the lower N contents in the irrigated amaranth relative to their non-irrigated counterpart in spite of the low soil N in the non-irrigated plots (Table 3 19), seems to indicate that other factors contributed to the poor growth and low utilization of nutrients

4 2 5 Effects of N and P fertilizers on plant chemical compositions

Only P fertilizer had significant effects on oxalate content in amaranth grown in each site (Table 4 26) The significantly lower total oxalate concentration in P-treated plants in Kukaiau and Waipio and the apparent decrease in Iole plants are in accordance with previous findings by Peck et al (1980) with table beets The cation-anion balance concept was inadequate to explain this effect (Table 4 33) since

Table 4 25

Effect of irrigation on total N and nitrate-N uptake
by amaranth grown at three sites

Irrigation	Kukaiau		Iole		Waipio	
	Total N	NO_3-N	Total N	NO_3-N	Total N	NO_3-N
	g/ 10 plants)					
Non-irrigated	2 83	1 26	4 13[a]	1 51[b]	1 00	0 19
Irrigated	1 65	0 65	1 83	0 51	1 01[a]	0 18[b]
Probability > |F|	0 1025	0 1138	0 6235	0 7761	0 8576	0 9738

a, b The two means superscripted by the same small letter are significantly different at 0 01 probability level (LSD test)

phosphorus application did not lower cation excess significantly relative to the non-P fertilizer treatments Peck et al (1980) found that P fertilizer lowered cation excess This study showed that in any particular site the sum of tissue cations was not affected by P fertilizer (Table 4 29) Plant K concentration, however, was significantly lowered by P fertilization relative to non-P treated plants in Kukaiau and Waipio On the other hand, Ca concentration was significantly higher in the P-treated Kukaiau plants and apparently increased in P-treated Iole plants Mg also decreased, but not significantly in the phosphorus plots in all sites Therefore P fertilizer in this study did not alter cation concentration in plants but did affect K and Ca and perhaps Mg differently

Table 4 26

Effects of fertilizers on various forms of oxalate in amaranth grown at three sites

Oxalate form	Fertilizer	Oxalate concentration (cmol kg^{-1} dry weight)					
		Kukaiau*		Iole*		Waipio*	
Total oxalate	Basal	214 6	A	190 7	A	173 3	A
	Basal+N	213 5	A	195 3	A	179 6	A
	Basal+P	184 9	B	176 6	A	145 9	B
Soluble oxalate	Basal	133 1	A	86 0	A	80 6	AB
	Basal+N	105 5	B	73 8	AB	96 9	A
	Basal+P	73 3	C	65 6	B	67 5	B
Insoluble oxalate	Basal	99 8	B	125 1	A	103 5	A
	Basal+N	104 6	B	127 5	A	115 5	A
	Basal+P	121 7	A	132 1	A	107 4	A
Soluble + insoluble oxalate	Basal	232 9	A	211 1	A	184 0	B
	Basal+N	210 1	B	201 3	A	212 4	A
	Basal+P	195 1	B	197 7	A	174 9	B

* Means of the same oxalate form and the same location followed by similar letter are not significantly different at 0 05 probability level (Waller-Duncan's multiple range test)

A significant decrease in soluble oxalate was observed in plants wherever phosphorus was applied (Table 4 26) This decrease was likely due to the effects of P fertilizer on decreasing K and probably Mg concentrations in the plants (Table 4 29) Significant increases in insoluble oxalate concentration in P-treated Kukaiau plants may be due to the additional Ca supplied to the plants by triple superphosphate The increase in the insoluble oxalate in Iole was not significant, however this is probably related to the fact that the soil there was well supplied with Ca

The insoluble oxalate content of amaranth in Waipio was not affected significantly by phosphorus fertilization (Table 4 26) The rate of phosphorus application was much less in Waipio (145 kg P ha^{-1}) than in either Kukaiau or Iole (225 kg P ha^{-1})

Nitrogen fertilizer did not significantly affect various forms of oxalates in Kukaiau and Iole, but did increase concentrations of various forms of oxalate in Waipio (Table 4 26) Previous work showed that addition of N (particularly in the form of nitrate) tended to increase organic acid in plants (Kirkby and Knight, 1977) Ben-Zioni et al (1970) observed the reduction of nitrate in leaves of corn tobacco and barley, resulted in build-up of cations in the tissue which in turn was neutralized by malic acid They observed a stoichiometric relation between the amount of nitrate reduced and malate accumulated

Correlation of N and P fertilizers with oxalates shows that P has negative relationships with total soluble and insoluble oxalates in non-irrigated plants and with soluble oxalate in irrigated plants N fertilizer exhibited a significant positive relationship with total oxalate in irrigated plants (Table 4 27)

Table 4 27

Correlation between N and P fertilizers with oxalates in irrigated and non-irrigated plots of amaranth

Irrigation	Fertilizer	Correlation coefficient[a] (Probability> |r|)			
		Total	Soluble	Insoluble	Soluble + insoluble
Non-irrigated	N	ns[b]	ns	ns	ns
	P	-0 3809 (0 0500)	-0 5385 (0 0038)	0 6174 (0 0006)	ns
Irrigated	N	0 4363 (0 0292)	ns	ns	ns
	P	ns	-0 4377 (0 0324)	ns	ns

[a]Number of observations = 27

[b]ns = Non-significant

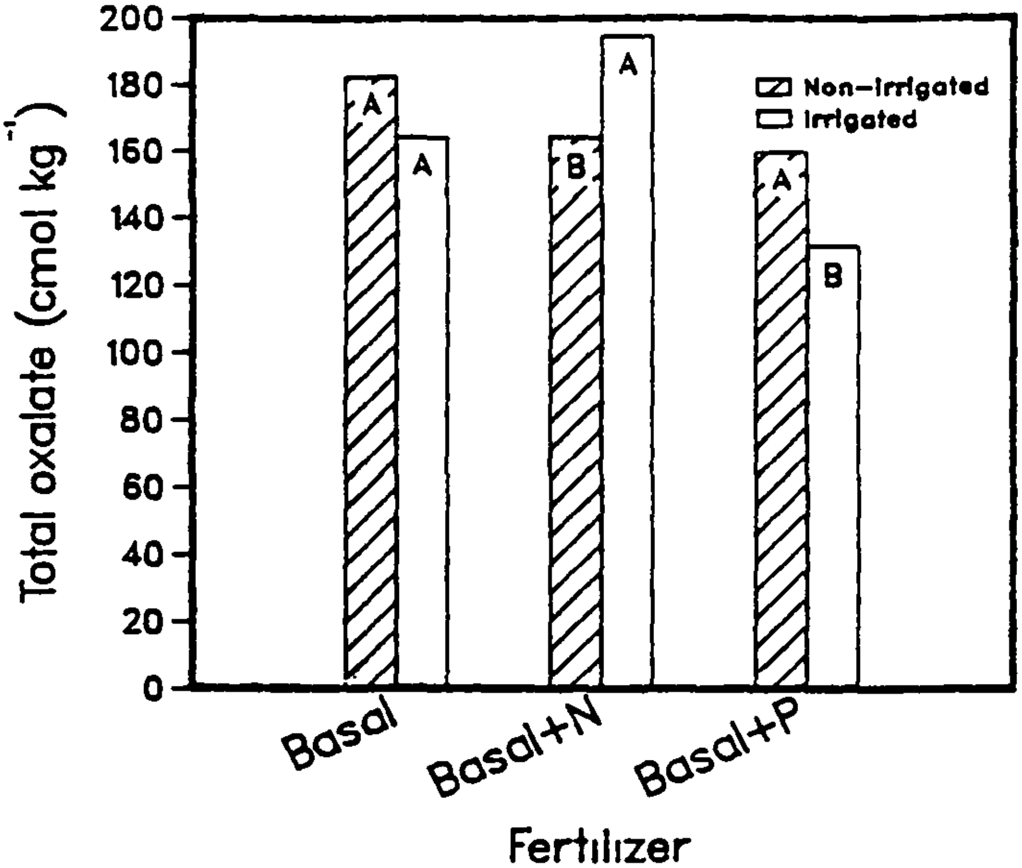
Although irrigation did not have significant effects on oxalates in amaranth grown in the three experimental sites, the effects of irrigation X fertilizer interaction on oxalate, N and ionic concentrations and uptake were significant in Waipio plants (Appendix A) Figure 4 11 illustrates the significant irrigation X fertilizer effect on total oxalate content Oxalate concentration was significantly higher in plants that received both nitrogen and irrigation N-fertilized irrigated plants from Waipio also had higher N uptake than those in non-irrigated plots (Figure 4 12) The higher N uptake was probably a key factor leading to higher oxalate content in N-treated irrigated plants

Table 4 28

Effects of fertilizers on the production of various forms of oxalate in amaranth grown at different sites

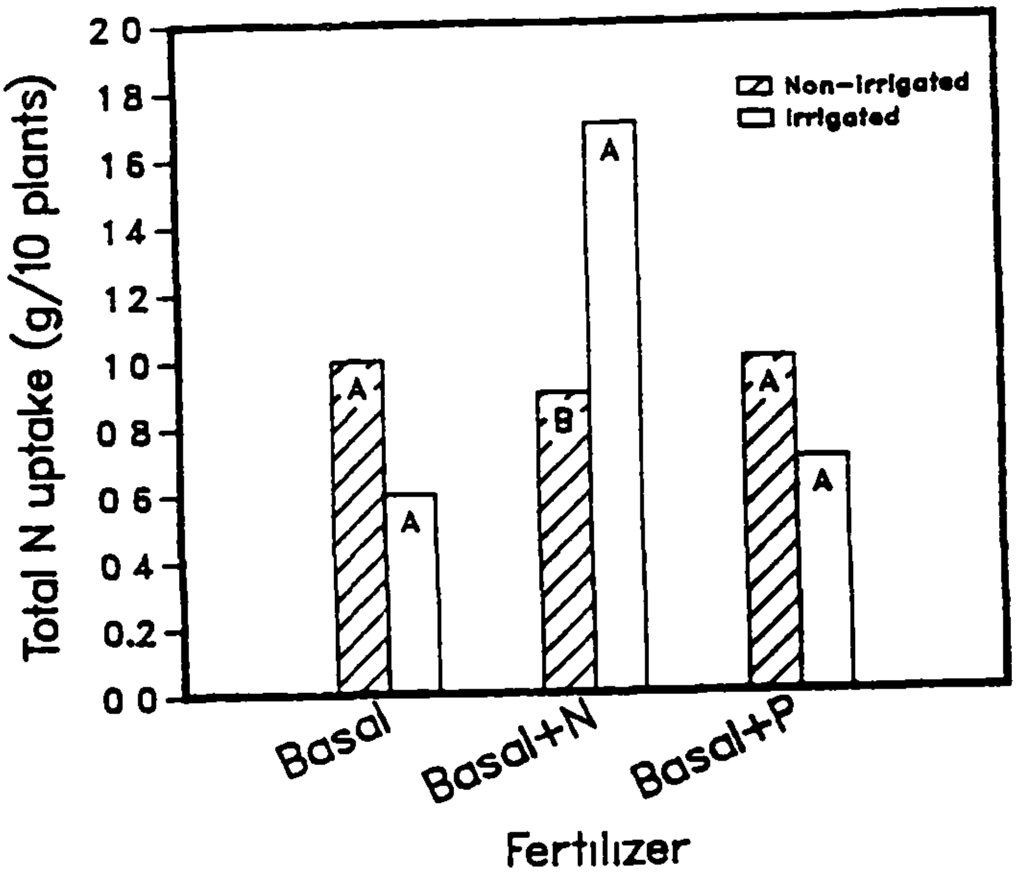
Oxalate	Fertilizer	Oxalate production (g/ 10 plants)		
		Kukaiau*	Iole*	Waipio*
Total oxalate	Basal+P	7 7 A	8 8 A	1 9 B
	Basal+N	3 2 B	8 9 A	2 9 A
	Basal	2 7 B	11 9 A	2 0 AB
Soluble oxalate	Basal+P	2 9 A	3 6 A	0 9 B
	Basal+N	1 5 A	3 0 A	1 6 A
	Basal	1 6 A	4 6 A	0 9 B
Insoluble oxalate	Basal+P	5 2 A	7 2 A	1 4 A
	Basal+N	1 6 B	6 2 A	1 9 A
	Basal	1 3 B	7 8 A	1 2 A
Soluble + insoluble oxalate	Basal+P	8 1 A	10 7 A	2 3 B
	Basal+N	3 1 B	9 2 A	3 4 A
	Basal	2 9 B	12 4 A	2 1 B

* Means of the same oxalate form and the same location followed by the same letter are not significantly different at 0 05 probability level (Waller-Duncan's multiple range test)



Means of the same fertilizer treatment with the same letter are not significantly different at 0 05 probability level (Waller-Duncan's multiple range test)

Figure 4 11 Effect of irrigation x fertilizer interaction on total oxalate concentration of amaranth grown at Waipio site



Means of the same fertilizer treatment with the same letter are not significantly different at 0 05 probability level (Waller-Duncan's multiple range test)

Figure 4 12 Effect of irrigation x fertilizer interaction on total N uptake of amaranth grown at Waipio site

Effects of N and P fertilizers on ionic concentration and uptake of amaranth

The effects of N and P fertilizers on cation concentrations in plants grown in different locations were not consistent (Table 4 29) The high Ca content in triple superphosphate fertilizer probably contributed to the higher plant Ca concentrations at both Kukaiau and Iole sites Previous work (Peck et al 1980) showed that P fertilization decreased cation concentrations in plants The apparent reduction in Mg and K of P-treated Kukaiau plants and Mg in P-treated Iole plants was observed It appeared that K concentrations in Iole plants were not affected by different fertilizer treatments On the other hand K was the dominant cation in plants grown at the Kukaiau site It is possible that the lower Ca and Mg concentrations in the soil at Kukaiau may have permitted K to be more readily absorbed

The increase in K concentration in N-fertilized plants at Waipio was the only sign which indicated the effect of N fertilizer on cation concentration in plants Plants at Kukaiau and Iole sites did not respond to N treatment suggesting that the soils already provided adequate N

The consistently higher cation uptake in P-treated plants of both Kukaiau and Iole sites suggests that the plant response to P created higher demand for these nutrients (Table 4 31)

N fertilization apparently led to higher cation uptake than other fertilizer treatments in Waipio plants (Table 4 31) This was because N created higher growth demand as indicated by higher dry matter production in N-treated Waipio plants (Table 4 2) Many studies show that

Table 4 29

Effects of N and P fertilizer applications on cation concentrations in amaranth grown at three sites

Site	Fertilizer	Ca*	Mg*	K*	Na*	SC**
		cmol kg^{-1} dry weight				
Kukaiau	Basal	115 3 B	99 3 A	154 6 A	5 2 A	374 3 A
	Basal+N	115 4 B	104 4 A	146 2 AB	4 7 A	370 0 A
	Basal+P	142 4 A	94 3 A	142 0 B	5 2 A	383 9 A
Iole	Basal	131 9 A	120 3 A	119 9 A	5 1 A	377 2 A
	Basal+N	131 6 A	122 0 A	115 7 A	4 4 B	373 7 A
	Basal+P	140 8 A	113 9 A	118 0 A	5 2 A	377 7 A
Waipio	Basal	100 4 A	116 8 A	105 0 B	8 7 A	330 8 A
	Basal+N	103 4 A	109 8 A	117 7 A	8 6 A	339 5 A
	Basal+P	102 8 A	110 7 A	102 0 B	8 4 A	323 8 A

* Means in the same column of each location followed by the same letter are not significantly different at 0 05 probability level (Waller-Duncan s multiple range test)

** Sum of cations concentration

N affects both absorption and translocation of ions (Barta, 1977) Pretreatment of N deficient roots with nitrate-N resulted in stimulation of strontium and cesium uptake and increased transport of strontium to the shoots (Jackson and Williams, 1968) Anderson and Jackson (1972) reported that nitrate-N pretreatment greatly increased Ca uptake and translocation to shoots Ammonium and urea pretreatment also increased translocation of Ca

The increased P, S and Cl concentrations and uptake (Table 4 30 4 32) in P-treated plants from Kukaiau and Iole was likely due to the effects of P fertilizer on increasing plant growth demand White (1973) found that the demand for P was associated with the rate of plant growth or the level of matabolic activity within the tissues, which appeared to have a marked influence on the rate of P uptake

Effects of N and P fertilizers on cation excess (C-A)

In general cation excess was not affected by N and P fertilizers The exception occurred in the N-treated plots in Kukaiau (Table 4 33) According to earlier workers (e g , Joy, 1964, Kirkby, 1968 Kirkby and Knight, 1977, Kirkby and Mengel, 1967, Peck et al , 1980) nitrogen fertilizer can increase cation excess above that of the controls while P treatment can decrease cation excess These trends can be seen in Waipio plants (Table 4 33) although the effects were not significant The irrigation X fertilizer interaction effect on cation excess of plants was also not significant at any site although there was a trend of N fertilizer to increase and P fertilizer to decrease oxalate in irrigated plants at Waipio

Table 4 30

Effects of fertilizers on anion concentrations in amaranth grown at three sites

Site	Fertilizer	P*	S*	NO_3*	Cl*	SA*
		cmol kg^{-1} dry weight				
Kukaiau	Basal	3 4 AB	7 7 B	24 8 B	6 8 B	42 6 B
	Basal+N	2 9 B	7 3 B	47 8 A	6 0 C	64 0 A
	Basal+P	4 0 A	10 0 A	20 5 B	8 4 A	42 9 B
Iole	Basal	2 2 B	10 3 A	20 7 B	6 9 B	40 2 B
	Basal+N	2 0 B	9 5 A	33 6 A	6 3 C	51 4 A
	Basal+P	3 5 A	10 4 A	17 3 B	7 3 A	38 5 B
Waipio	Basal	2 9 B	9 6 A	8 3 A	7 7 A	28 4 A
	Basal+N	2 7 B	9 2 A	12 7 A	7 3 B	31 9 A
	Basal+P	4 0 A	9 2 A	7 8 A	7 9 A	28 9 A

* Means in the same column of each location followed by the same letter are not significantly different at 0 05 probability level (Waller-Duncan s multiple range test)

** Sum of anions concentration

Table 4 31

Effects of fertilizers on cation uptake by amaranth grown at three sites

Site	Fertilizer	Ca*	Mg*	K*	Na*
		g/ 10 plants			
Kukaiau	Basal	0 67 B	0 33 B	1 70 B	0 03 B
	Basal+N	0 81 B	0 41 B	1 97 B	0 04 B
	Basal+P	2 69 A	1 05 A	5 02 A	0 11 A
Iole	Basal	3 42 A	1 73 A	5 64 A	0 13 A
	Basal+N	2 86 A	1 41 A	4 26 A	0 10 A
	Basal+P	3 92 A	1 44 A	5 05 A	0 13 A
Waipio	Basal	0 54 A	0 35 A	1 05 B	0 04 B
	Basal+N	0 73 A	0 48 A	1 66 A	0 08 A
	Basal+P	0 62 A	0 38 A	1 17 AB	0 05 AB

* Means in the same column of the same location followed by the same letter are not significantly different at 0 05 probability level (Waller-Duncan s multiple range test)

Table 4 32

Effects of fertilizers on anion uptake by amaranth grown at three sites

Site	Fertilizer	P*	S*	NO_3*	Cl*
		g/10 plants			
Kukaiau	Basal	0 08 B	0 10 B	0 51 A	0 07 B
	Basal+N	0 10 B	0 12 B	1 06 A	0 07 B
	Basal+P	0 33 A	0 45 A	1 29 A	0 28 A
Iole	Basal	0 25 A	0 58 A	1 44 A	0 31 A
	Basal+N	0 17 A	0 47 A	1 66 A	0 23 A
	Basal+P	0 37 A	0 53 A	1 27 A	0 28 A
Waipio	Basal	0 07 A	0 12 A	0 13 B	0 07 A
	Basal+N	0 10 A	0 16 A	0 28 A	0 09 A
	Basal+P	0 10 A	0 13 A	0 14 B	0 08 A

* Means in the same column of the same location followed by the same letter are not significantly different at 0 05 probability level (Waller-Duncan's multiple range test)

Table 4 33

Effects of N and P fertilizers on cation excess in amaranth grown at three sites

Fertilizer	Cation excess (cmol kg^{-1} dry weight		
	Kukaiau*	Iole*	Waipio*
Basal	331 6 A	337 0 A	302 5 A
Basal+N	306 1 B	322 4 A	306 7 A
Basal+P	341 1 A	339 2 A	294 9 A

* Means in the same column followed by the same letter are not significantly different at 0 05 probability level (Waller-Duncan's multiple range test)

There are many factors which might have prevented the expected response of cation excess to N and P fertilizers in Kukaiau and Iole plants to be detected but permit it to be expressed in the Waipio plants The first factors involve N metabolism N fertilizer applied in urea form was likely to be transformed to nitrate before being absorbed by the plants The accumulation of nitrate was significantly higher in N-treated plants at Kukaiau and Iole than those treated with the other fertilizers, but such accumulation was not significantly different among different fertilizer treatments in Waipio plants (Table 4 35) This shows that in Kukaiau and Iole, high unassimilated nitrate content led to low cation excess content especially in N-treated Kukaiau and Iole plants On the other hand Waipio plants had lower nitrate accumulation (Table 4 35) suggesting that most of the nitrate was assimilated into protein resulting in increased cation excess

Amaranth grown at the Waipio site may have had higher nitrate reductase activity than those in Kukaiau and Iole Nitrate reductase activity has been found to be affected by environmental factors, such as light intensity, temperature and soil moisture Cantliffe (1972b) found that high light intensity promoted the high activity of nitrate reductase Waipio plants received higher solar radiation than Kukaiau and Iole plants (Table 3 20)

The second factor for the weak causal relationship between cation excess and N and P fertilizer application may involve the use of triple superphosphate as the source of P P fertilizer was expected to reduce cation excess because it often reduces cation concentration For example, Peck et al (1980) found that increasing rates of P fertilizer reduced cation concentration in table beets Triple superphosphate, however, contains high amounts of Ca resulting in high tissue Ca concentrations in P-treated Kukaiau and Iole plots These high Ca concentrations are to have prevented P from reducing cation excess in Kukaiau and Iole On the other hand Waipio plants received a lower rate of P Moreover, the lower Ca concentration in these plants (Table 4 29) shows that the cation excess of these P-treated plants are not influenced by Ca to the same extent as P-treated Kukaiau and Iole plants Apparent response of cation excess to P fertilizer was shown in the Waipio plants (Table 4 33)

Effects of N and P fertilizers on total N and nitrate-N concentrations and uptake

Total N concentration was higher in N-fertilized plants in all sites, while P fertilizer reduced total N concentration (Table 4 34)

Total N uptake was significantly higher in P-fertilized plants in Kukaiau and Iole than in plants treated with basal fertilizer On the other hand, in Waipio total N uptake was significantly higher in the N-treated plants (Table 4 34)

Table 4 34

Effects of fertilizers N and P on total N concentrations and uptake in amaranth grown at three sites

Fertilizer	Concentration (% dry weight)			Uptake (g/ 10 plants)		
	Kukaiau*	Iole*	Waipio*	Kukaiau*	Iole*	Waipio*
Basal+N	5 06 A	4 68 A	3 53 A	1 74 B	2 81 A	1 27 A
Basal	4 47 B	4 15 A	3 26 AB	1 26 B	2 17 A	0 82 B
Basal+P	4 06 C	4 06 A	3 06 B	3 71 A	4 18 A	0 88 B

* Means in the same column followed by the same letter are not significantly different at 0 05 probability level (Waller-Duncan's multiple range test)

Nitrate-N concentration varied with fertilizer treatments in the same way as total N concentration (Table 4 35) Nitrate-N uptake by Kukaiau and Iole plants was highest in P-treated plants and in N-treated plants in the Waipio plants (Table 4 35)

4 2 6 Relationships between oxalates, nitrate and agroenvironmental factors

All forms of oxalates with the exception of insoluble oxalate were significantly negatively correlated with subsoil temperature

Table 4 35

Effects of N and P fertilizers on nitrate-N concentration and uptake by amaranth grown at the three sites

Fertilizer	Concentration (% dry weight)			Uptake (g/ 10 plants)		
	Kukaiau*	Iole*	Waipio*	Kukaiau*	Iole*	Waipio*
Basal+N	0 67 A	0 47 A	0 10 A	1 06 A	1 27 A	0 25 A
Basal	0 35 B	0 29 B	0 12 A	0 51 A	0 73 A	0 13 B
Basal+P	0 29 B	0 24 B	0 11 A	1 29 A	1 19 A	0 14 B

* Means from the same column followed by the same letter are not significantly different at 0 05 probability level (Waller-Duncan s multiple range test)

(Table 4 36) Significant correlations were found more often with soil temperature than with air temperature All correlations were negative except for that between air temperature and soluble oxalate Other studies on the relationship between temperature and plant oxalates although scarce, also indicate the negative relationship between the two variables Kitchen et al (1964b) postulated that at high temperatures more oxalic acid was used as a respiratory substrate

Nitrate-N was also negatively correlated with air and soil temperature (Table 4 36) Temperature can increase nitrate content due to diminished nitrate reductase activities at high temperature (Cantliffe, 1972a) In this study other factors appeared to override the temperature effect The most significant factor was soil

Table 4 36

Correlation between amaranth oxalates or nitrate content with air or soil temperature at three experimental sites

Plant Chemical	Correlation coefficient (Probability > |r|)											
	Air temperature				Topsoil temperature				Subsoil temperature			
	Max	Min	Av	Dif*	Max	Min	Av	Dif	Max	Min	Av	Dif
Total oxalate	ns	ns	ns	0 5267 (0 0001)	ns (0 0442)	0 2803 (0 0001)	ns (0 0001)	0 5181 (0 0001)	0 5646 (0 0001)	0 5636 (0 0001)	0 5653 (0 0001)	0 4332 (0 0001)
Soluble oxalate	ns	0 3449 (0 0132)	ns	ns	ns	ns	ns	0 3976 (0 0039)	0 3775 (0 0063)	0 3562 (0 0103)	0 3717 (0 0072)	0 4532 (0 0008)
Insoluble oxalate	0 4256 (0 0019)	0 3375 (0 0154)	0 4240 (0 0091)	ns	0 3593 (0 0096)	0 3048 (0 0296)	0 3377	ns	ns	ns	ns	0 2707 (0 0547)
Soluble + Insoluble oxalate	ns	ns	ns	0 3573 (0 0101)	ns	ns	ns	0 3190 (0 0225)	0 3620 (0 0091)	0 3619 (0 0091)	0 3620 (0 0090)	ns
Nitrate N	0 3046 (0 0281)	ns	ns	0 5439 (0 0001)	ns	0 4172 (0 0021)	0 3470 (0 0117)	0 6208 (0 0001)	0 6206 (0 0001)	0 6241 (0 0001)	0 6225 (0 0001)	0 4134 (0 0023)

Dif Difference between maximum and minimum values

ns non significant

N content For example, Waipio the site with the highest temperature had relatively lower soil N

Plant oxalate and nitrate were positively correlated with rainfall (Table 4 37) Adequate water supply provided by rains may facilitate ion uptake by roots which enhances oxalate synthesis and nitrate accumulation Radiation on the other hand, exhibited negative correlation with both oxalates and nitrate (Table 4 37) Long exposure to high light intensity was found to decrease nitrate content due to an increase in nitrate reductase activity (Cantliffe, 1972a and b) The high plant nitrate levels in Iole and Kukaiau relative to those in Waipio can be attributed to the lower radiation and higher soil nitrogen in Iole and Kukaiau than in Waipio

Nitrate content was also negatively correlated with wind speed (Table 4 37) It has been postulated that factors that cause higher transpiration rates can lead to more rapid nitrate translocation to the site of reduction therefore, resulting in lower nitrate accumulation (Maynard et al 1976)

Oxalates and nitrate were positively correlated with soil total N, but they showed a negative relationship with the other soil variables (Table 4 38, Figures 4 13-4 17) Earlier work has shown that N assimilation leads to synthesis of organic acid (e g Ikeda and Yamada 1981) In addition, high soil N leads to high N absorption and increased organic acid synthesis The negative correlation of plant oxalates and nitrate with soil bases was most likely due to the inability of the plants to utilize the soil bases because of low soil N For example the Tropeptic Eutrustox in Waipio had a high base

Table 4 37

Correlation between oxalates nitrate and some climatic factors, including rainfall, radiation wind speed and relative humidity in amaranth

Chemical composition	Correlation coefficient*** (Probability > |r|)						
	Rainfall	Radiation	Wind speed	Relative humidity			
				Maximum	Minimum	Average	Dif*
Total oxalate	0 3740 (0 0063)	-0 4881 (0 0002)	-0 4824 (0 0003)	ns**	ns	ns	-0 4116 (0 0024)
Soluble oxalate	ns	ns	ns	-0 2923 (0 0374)	ns	ns	-0 3062 (0 0289)
Insoluble oxalate	0 4527 (0 0009)	ns	ns	0 4881 (0 0003)	0 5411 (0 0001)	0 5317 (0 0001)	ns
Soluble + insoluble oxalate	0 3265 (0 0194)	-0 3321 (0 0173)	ns	ns	ns	ns	-0 3993 (0 0037)
Nitrate N	0 3816 (0 0053)	-0 5727 (0 0001)	-0 6507 (0 0001)	ns	0 2720 (0 0511)	ns	-0 3064 (0 0272)

* Dif = Difference between maximum and minimum relative humidity
** ns - non-significant
*** Number of observations = 54

Table 4 38

Correlation between amaranth oxalates, nitrate and some soil variables at three experimental sites

	Correlation coefficient** (Probability > |r|)					
Chemical composition	Soil N	Soil Ca	Soil Mg	Soil K	Soil Na	Soil P
Total oxalate	0 5421 (0 0001)	-0 5094 (0 0001)	-0 5571 (0 0001)	-0 3320 (0 0162)	-0 3734 (0 0064)	-0 2477 (0 0766)
Soluble oxalate	ns*	-0 3551 (0 0106)	ns	ns	ns	ns
Insoluble oxalate	ns	ns	ns	ns	ns	ns
Soluble + insoluble oxalate	0 3812 (0 0058)	-0 5075 (0 0001)	-0 4239 (0 0019)	-0 2706 (0 0548)	ns	-0 3042 (0 0300)
Nitrate-N	0 5983 (0 0001)	-0 5495 (0 0001)	-0 6154 (0 0001)	-0 4742 (0 0004)	-0 3832 (0 0050)	ns

* ns = non-significant
** Number of observations = 54

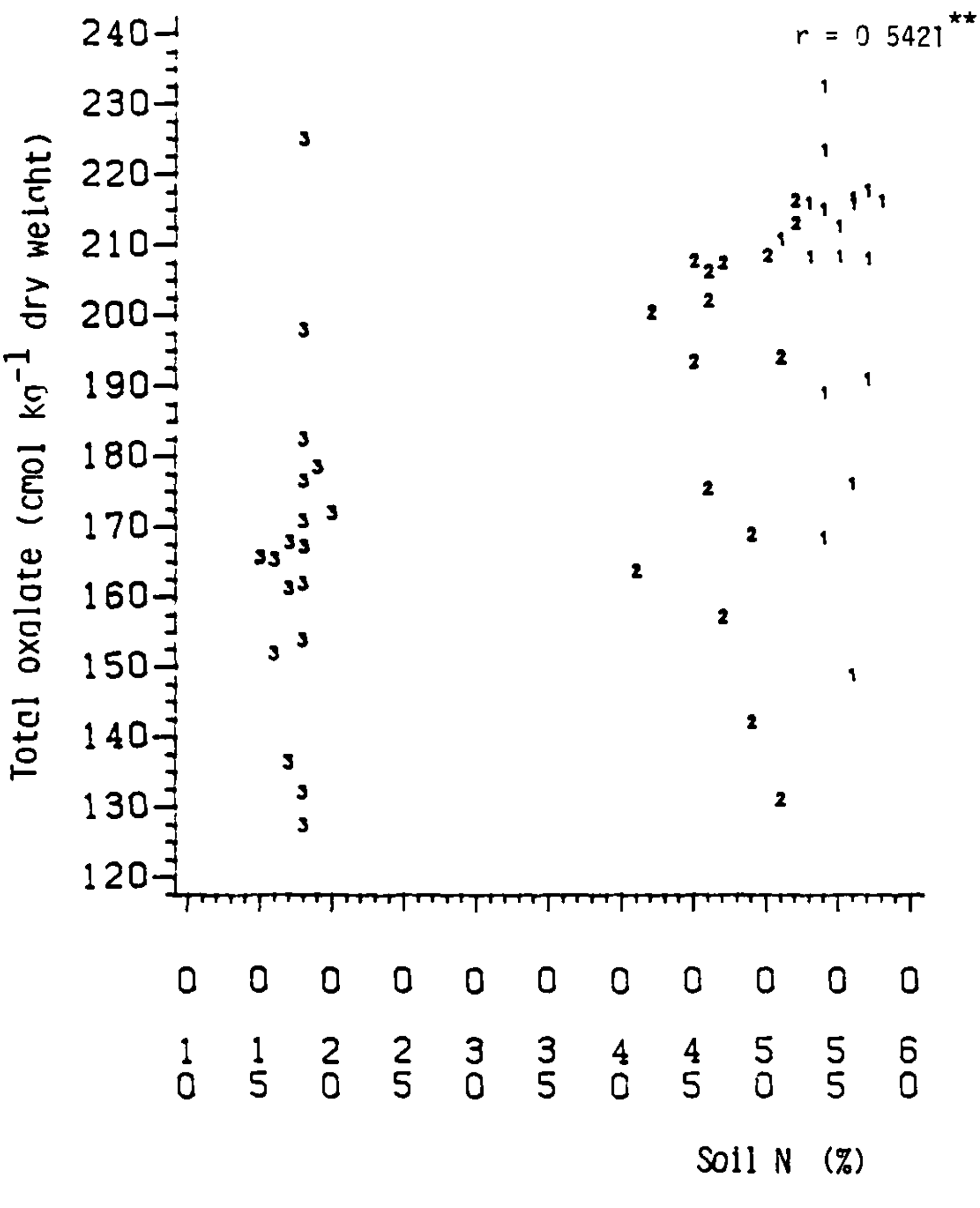


Figure 4 13 Relationship between tissue total oxalate of amaranth and soil nitrogen from experiments at three sites (1=Kukaiau, 2=Iole, 3=Waipio)

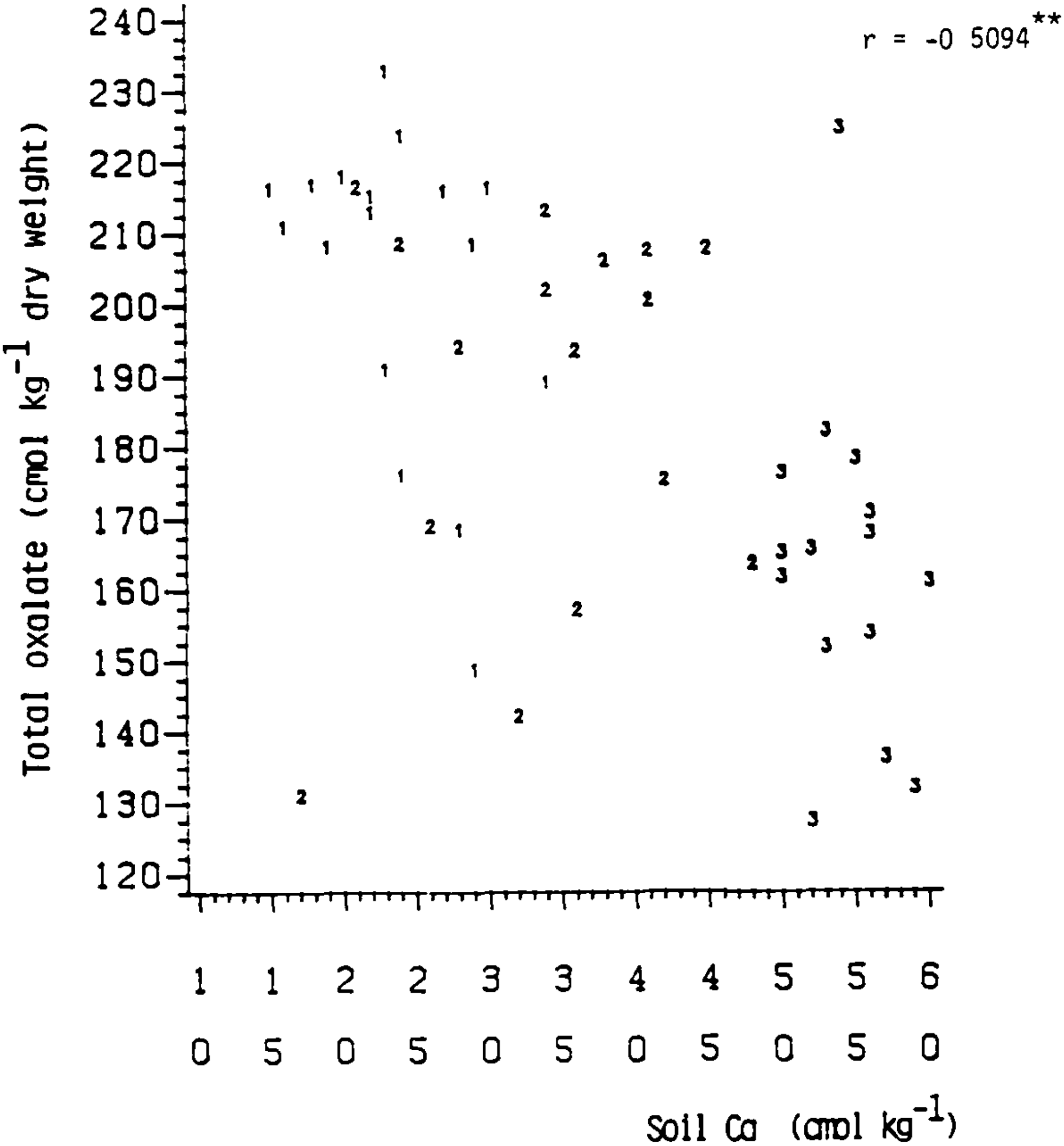


Figure 4 14 Relationship between tissue total oxalate of amaranth and soil Ca from experiments at three sites (1=Kukaiau, 2=Iole, 3=Waipio)

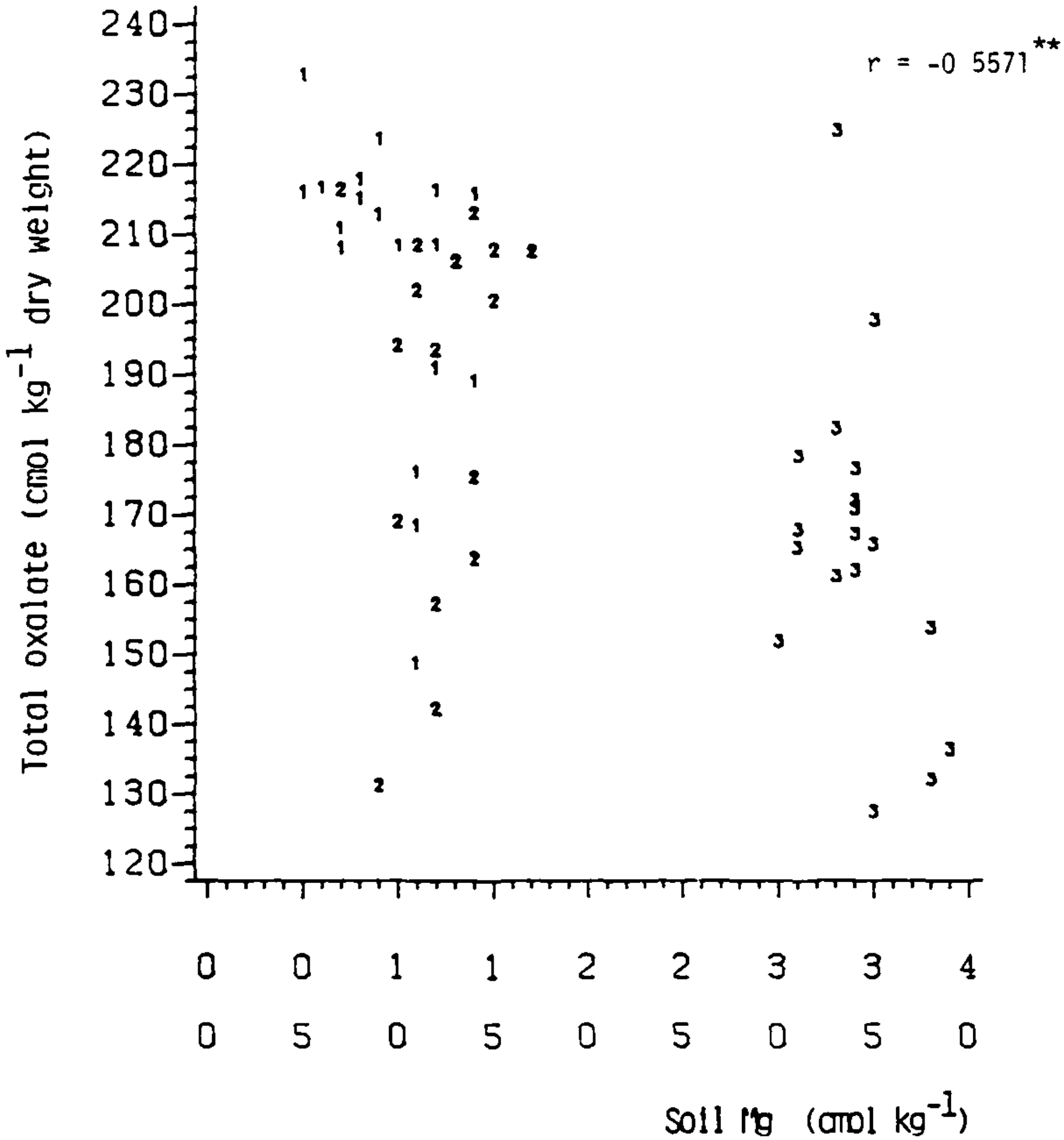


Figure 4 15 Relationship between tissue total oxalate of amaranth and soil Mg from experiments at three sites (1=Kukaiau, 2=Iole, 3=Waipio)

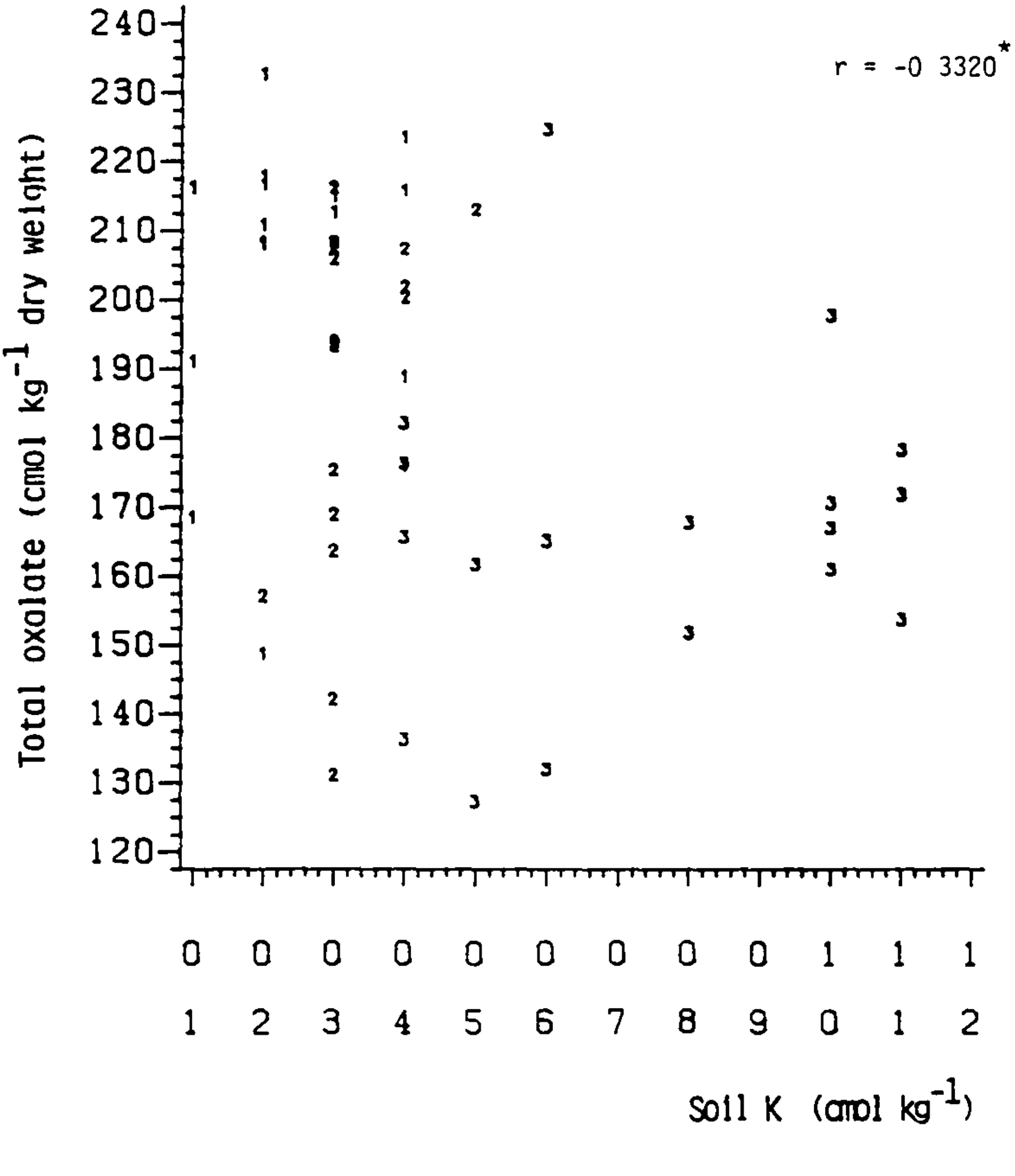


Figure 4 16 Relationship between tissue total oxalate of amaranth and soil K from experiments at three sites (1=Kukaiau, 2=Iole, 3=Waipio)

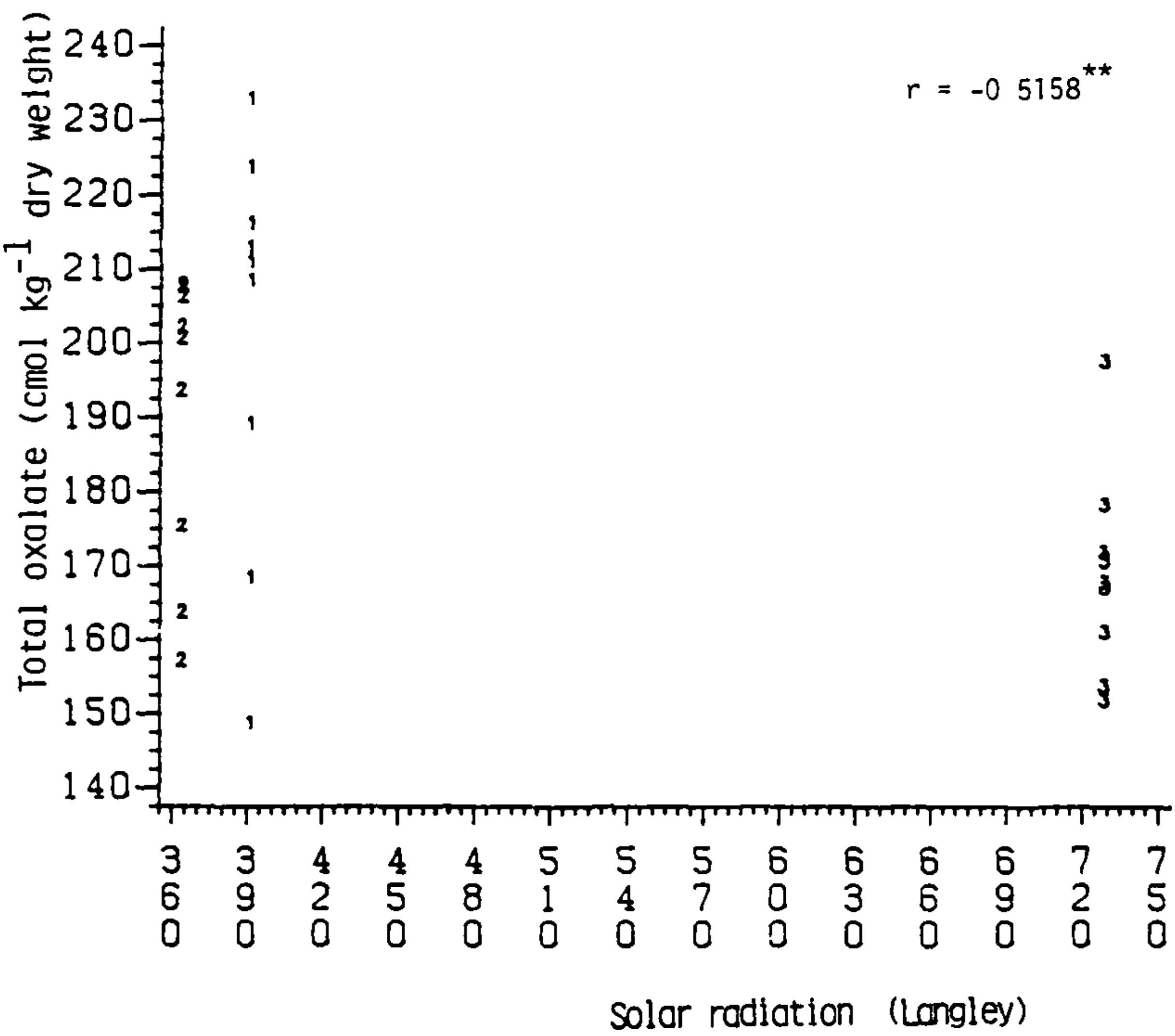


Figure 4 17 Relationship between tissue total oxalate of amaranth and solar radiation from non-irrigated plots of experiments at three sites
(1=Kukaiau, 2=Iole 3=Waipio)

status but low N As a consequence, the plants at this site suffered mild N stress and did not absorb other nutrients efficiently The low level of N and low cation uptake led to low contents of oxalate and nitrate despite the high base status of the soil

Soil P was negatively correlated with oxalates (Table 4 38) and this is consistent with the tendency of P to reduce the cation excess in plants

Multiple regression analysis of the relationships between oxalate, nitrate and agroclimatic factors

Multiple regression analysis of data from irrigated and non-irrigated plots were conducted separately to minimize the variance associated with irrigation treatments described earlier in section 4 2 4 Irrigation treatments by themselves did not result in significant effects on oxalate and nitrate concentrations in amaranth with the exception of the insoluble oxalate and nitrate in Iole plants (Tables 4 20, 4 24) Significant interaction effects however, were found For example, the effects of site x irrigation and site x irrigation x fertilizer on nitrate-N content were significant (Appendix A)

The regression equation for total oxalate concentration in non-irrigated amaranth is presented in Table 4 39 The negative relationships of oxalate concentration with mean solar radiation and P fertilizer rate were as shown in Figures 4 17 4 18 P fertilizer has decreased oxalate in table beets (Peck et al 1980) apparently because P fertilizer decreased uptake and concentration of cations by plants and therefore decreased cation excess Soil Mg and K contributed positively to oxalate production since their uptake increase cation

Table 4 39

Multiple regression equation for total oxalate concentration in amaranth from non-irrigated plots of three experimental sites

Variable*	Regression coefficient	Standard error	t	Probability > |t|
Intercept	225 261	7 4549	30 217	0 0001
SRSQ	-0 000025	0 000061	-0 400	0 6934
PLEVEL	-0 0894	0 0421	-2 121	0 0454
SOLMG	36 3598	13 5733	-2 679	0 0137
SOLK	84 7203	42 4200	1 997	0 0583

Model r^2 = 0 6123

Model Adj r^2 = 0 5419

*SRSQ = Square of solar radiation
PLEVEL = Fertilizer P rate
SOLMG = Soil Mg content
SOLK = Soil K content

excess The negative correlations of soil Mg and K with oxalate (Figures 4 15 and 4 16) were probably due to their interaction with soil N Although soil Mg and K were high at the Waipio site the plants did not absorb a large amount of Mg and K due to low N supply

In the irrigated treatments, solar radiation gave rise to a positive parameter estimate (Table 4 40) in spite of its negative correlation with total oxalate (Figure 4 19) The difference between maximum and minimum air temperature however gave rise to negative regression coefficient This is consistent with the negative

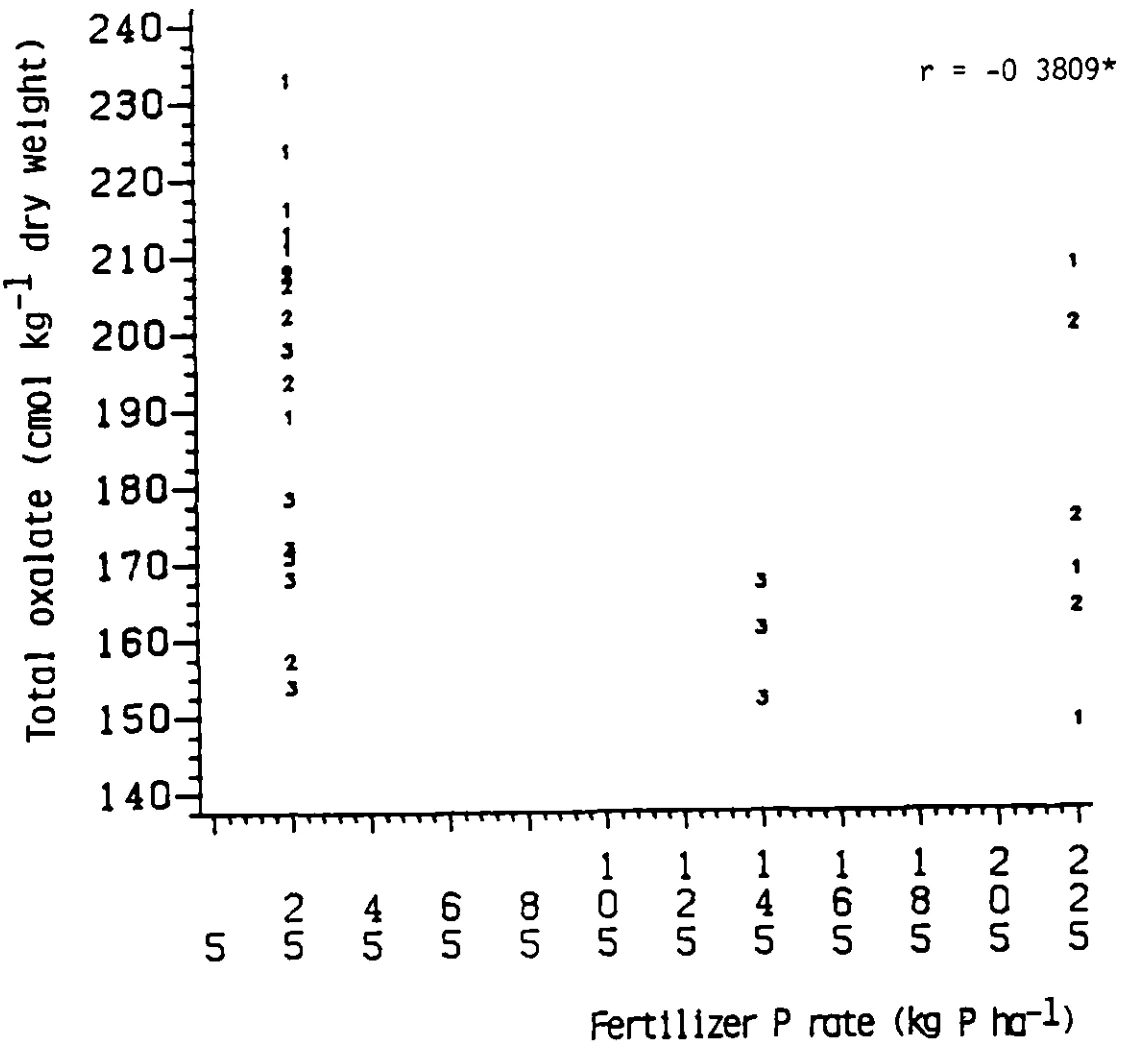


Figure 4 18 Relationship between tissue total oxalate of amaranth and fertilizer P rate from non-irrigated plots of experiments at three sites (1=Kukaiau, 2=Iole 3=Waipio) relationship between this variable and total oxalate (Appendix D) The difference between maximum and minimum air temperature exhibited curvilinear relationship with total oxalate To take into account the non-linear relationship in the regression studies the difference between maximum and minimum air temperature was squared Solar radiation and the square of the difference between maximum and minimum temperature were highly correlated (r = 0 9996, Appendix D) This may be due to clear skies giving rise to high radiation and warm temperature during the day and low temperature at night The fact that the two variables gave rise to opposite signs of the regression coefficient (Table 4 40) indicated that they contributed to oxalate production in different ways

Fertilizer N rate also gave rise to a positive regression co-efficient which was consistent with the positive correlation between this variable and total oxalate (Figure 4 20)

The regression model for soluble oxalate in non-irrigated amaranth with the related statistics is shown in Table 4 41 Not unexpectedly soil K explained a significant amount of variance in soluble oxalate as soluble oxalate occurred primarily as potassium oxalate P fertilizer rate and soil Ca were negatively correlated with soluble oxalate and the relationship was in accordance with their negative relationships with soluble oxalate (Figures 4 21 4 22 Appendix C) P fertilizer is also a source of Ca for the plants The regression coefficient of soil P was positive (Table 4 41) however it was negatively related to soluble oxalate as shown in Figure 4 14 Appendix C P usually brings about a reduction in cation excess which in turn, results in a decrease in oxalate concentration It is likely

Table 4 40

Multiple regression equation for total oxalate concentration in amaranth from irrigated plots at three experimental sites

Variable*	Regression coefficient	Standard error	t	Probability > |t|
Intercept	1991 572	659 811	3 018	0 0068
SRSQ	0 0059	0 0022	2 688	0 0141
NLEVEL	0 1791	0 0503	3 557	0 0020
SOLK	105 048	54 8168	1 916	0 0697
AIR4SQ	-30 9963	11 2800	-2 748	0 0124

Model r^2 = 0 6076

Model Adj r^2 = 0 5291

* SRSQ = Square of solar radiation

NLEVEL = Fertilizer N rate

SOLK = Soil K concentration

AIR4SQ = Square of the difference between maximum and minimum temperature

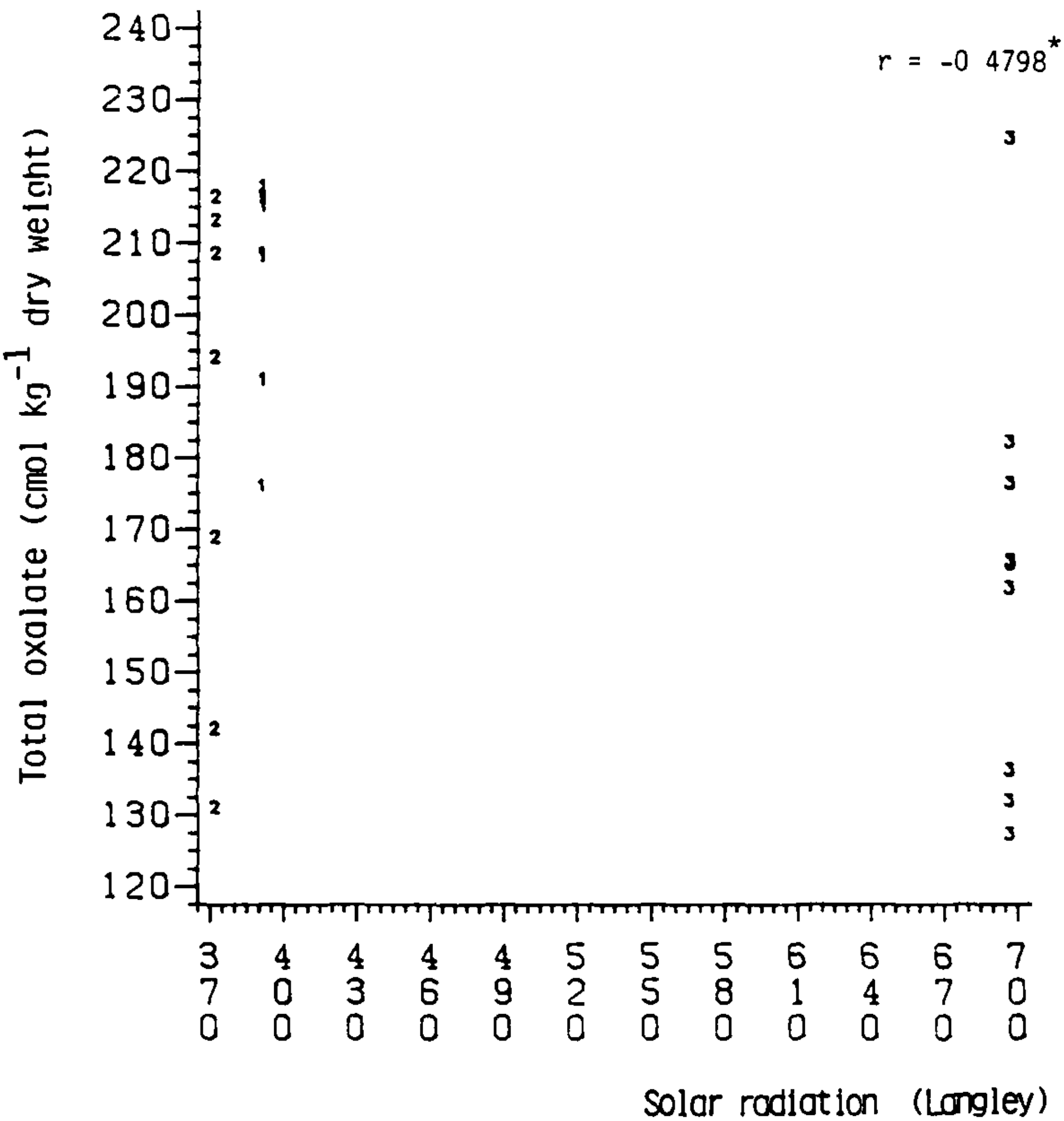


Figure 4 19 Relationship between tissue total oxalate of amaranth and solar radiation from irrigated plots of experiments at three sites
(1=Kukaiau, 2=Iole 3=Waipio)

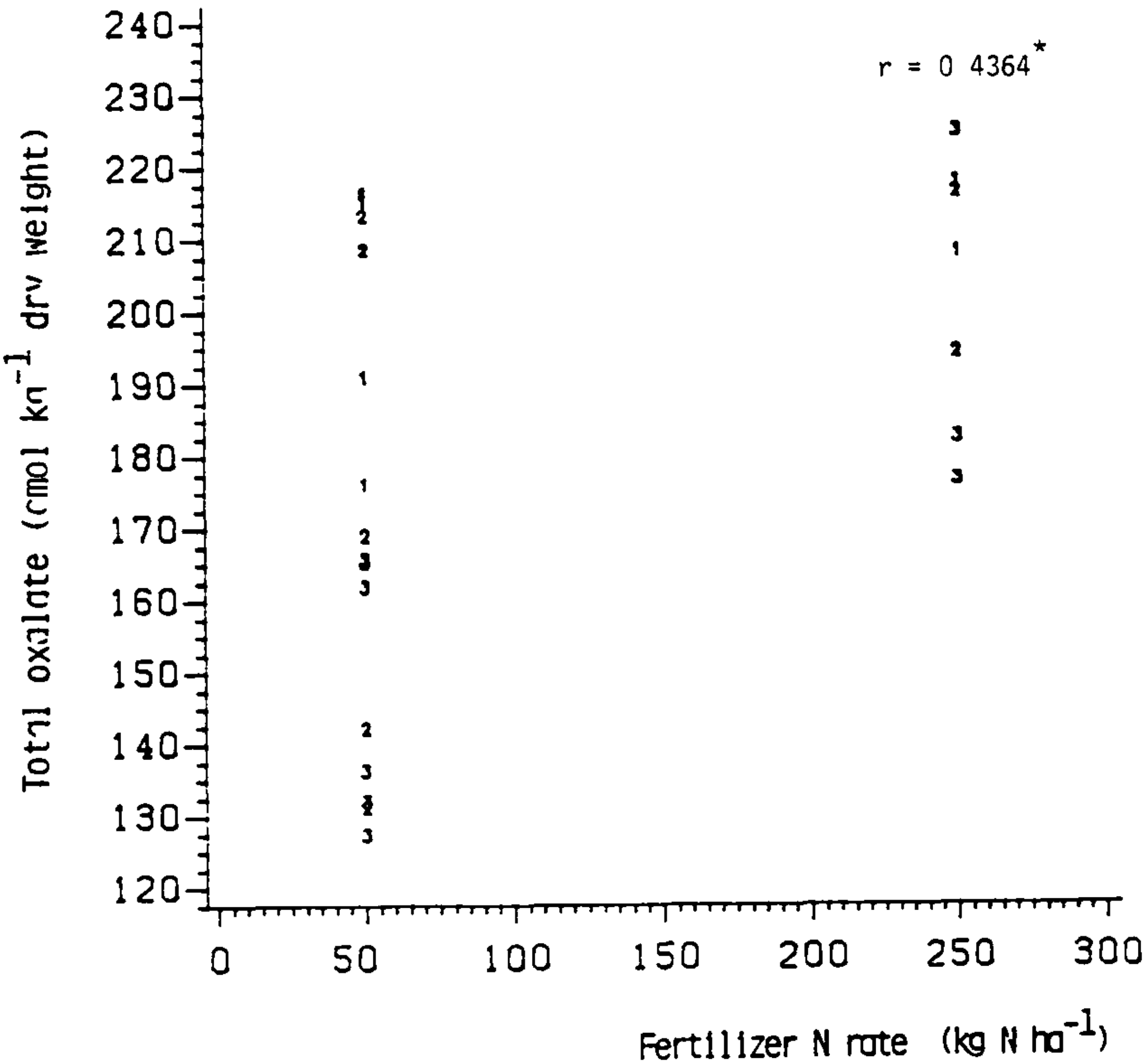


Figure 4 20 Relationship between tissue total oxalate of amaranth and fertilizer N rate from irrigated plot of experiments at three sites
(1=Kukaiau, 2=Iole, 3=Waipio)

Table 4 41

Multiple regression equation for soluble oxalate concentration in amaranth from non-irrigated plots of three experimental sites

Variable*	Regression coefficient	Standard error	t	Probability > |t|
Intercept	113 253	20 3643	5 561	0 0001
SOLK	56 5055	21 8189	2 590	0 0167
PLEVEL	-0 1698	0 0603	-2 818	0 0100
SOLCA	-18 7353	4 8909	-3 831	0 0009
SOLP	0 4673	0 2815	1 660	0 1110

Model r^2 = 0 6359

Model Adj r^2 = 0 5698

* SOLK = Soil K concentration
PLEVEL = Fertilizer P rate
SOLCA = Soil Ca concentration
SOLP = Soil P concentration

that fertilizer P affected plant growth more than initial soil P and this is supported by the fact that soil P did little to explain the variance in soluble oxalate (Table 4 41) Because soil P was measured at harvest it included both the P applied as fertilizer and initial soil P In the multiple regression analysis both variables were retained but only P level was significant This is due to the fact that P level and soil P were highly correlated

The regression analysis of soluble oxalate in irrigated plants is shown in Table 4 42 In accordance with the positive relationship

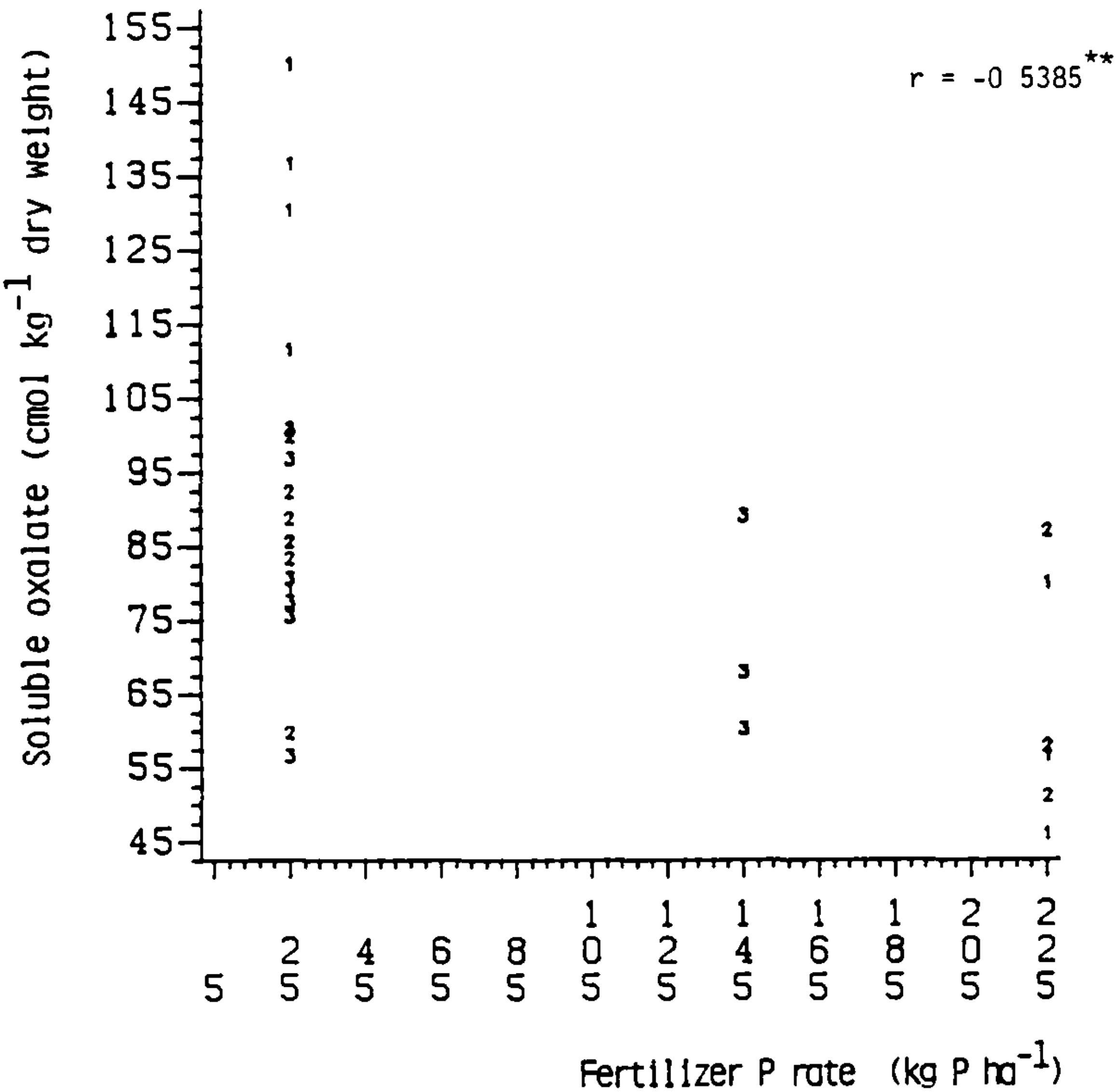


Figure 4 21 Relationship between tissue soluble oxalate of amaranth and fertilizer P rate from non-irrigated plots of experiments at three sites
(1=Kukaiau 2=Iole 3=Waipio)

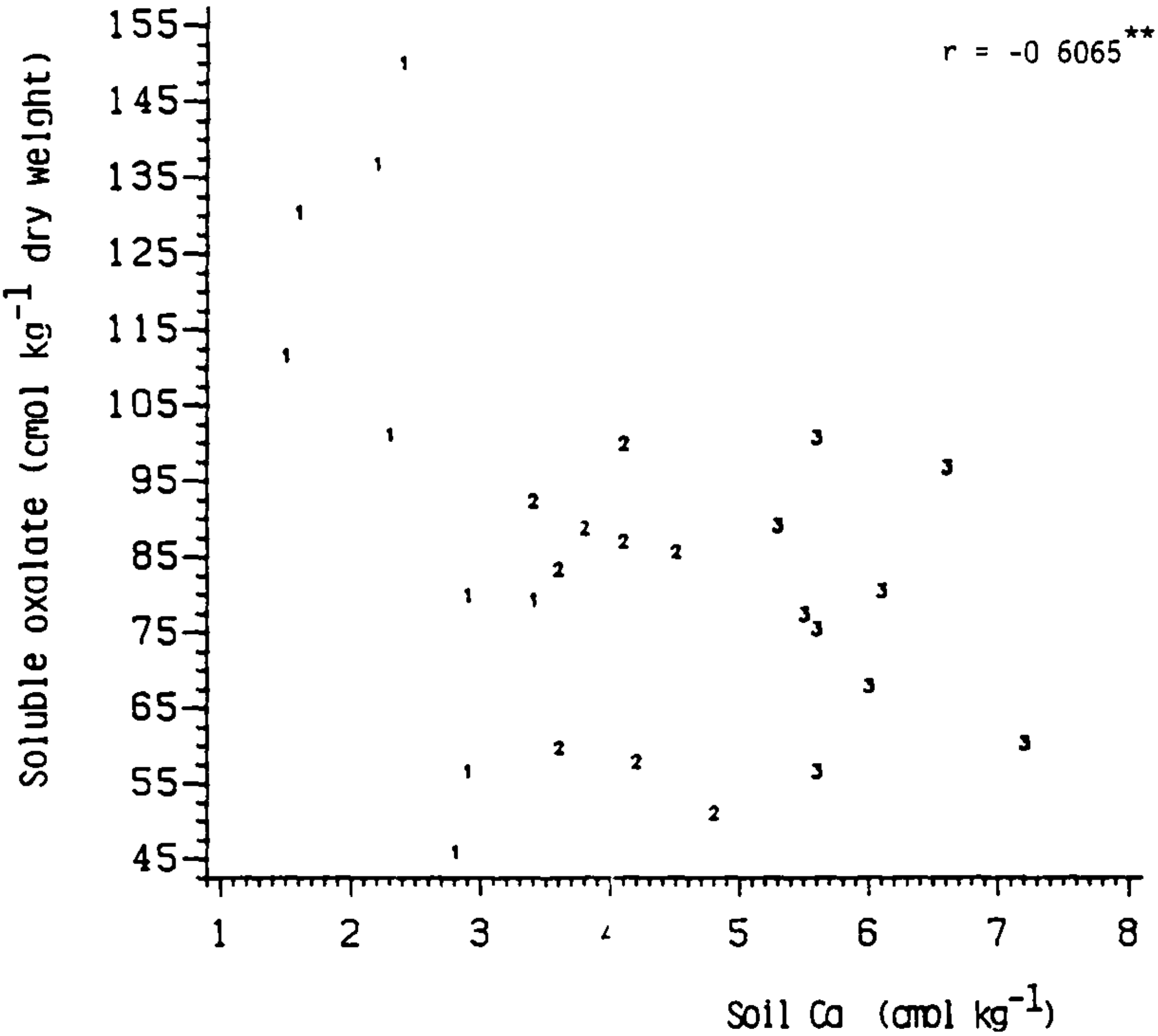


Figure 4 22 Relationship between tissue soluble oxalate of amaranth and soil Ca from non-irrigated plots of experiments at three sites
(1=Kukaiau 2=Iole 3=Waipio)

Table 4 42

Multiple regression equation for soluble oxalate concentration in amaranth from irrigated plots of three experimental sites

Variable*	Regression coefficient	Standard error	t	Probability > |t|
Intercept	-109 043	47 0516	-2 318	0 0306
AIR2	13 9927	3 1128	4 495	0 0002
PLEVEL	-0 1439	0 0430	-3 350	0 0031

Model r^2 = 0 5880

Model Adj r^2 = 0 5488

* AIR2 = Minimum air temperature

PLEVEL = Fertilizer P rate

between soluble oxalate and minimum air temperature (Figure 4 23) this variable also gave rise to a positive parameter estimate The effect of air temperature on soluble oxalate concentration was positive while the effect on total and insoluble oxalate was negative Fertilizer P rate also produced negative regression coefficient in accordance with its negative relationship with soluble oxalate (Figure 4 24)

The regression model for insoluble oxalate concentration in non-irrigated plants is shown in Table 4 43 Only variables related to P supply significantly influenced insoluble oxalate Although soil P was not significantly related with insoluble oxalate (Appendix C) the regression coefficient was significantly negative in this equation The reason put forward earlier that P being an anion tends to decrease

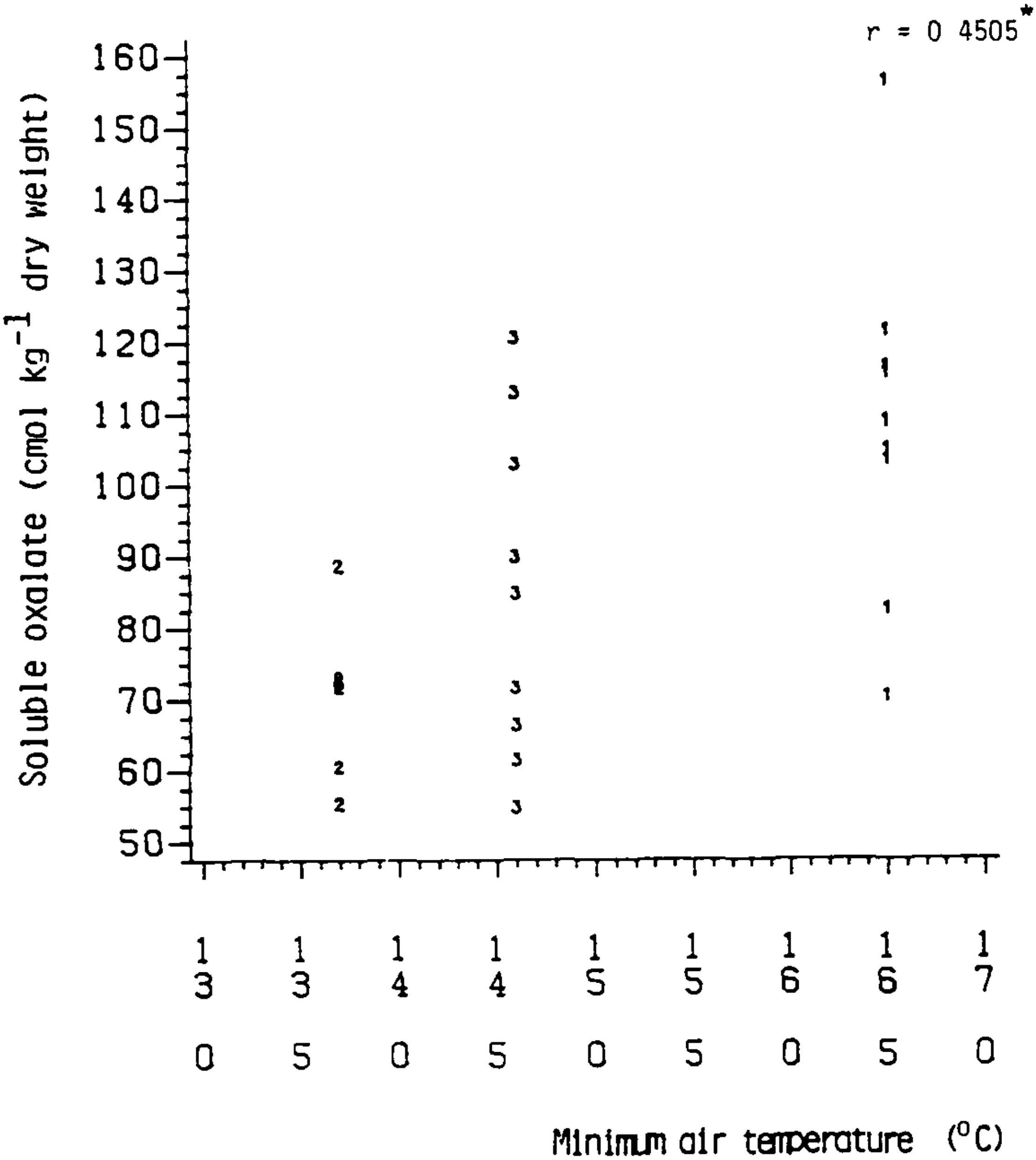


Figure 4 23 Relationship between tissue soluble oxalate of amaranth and minimum air temperature from irrigated plots of experiments at three sites (1=Kukaiau, 2=Iole, 3=Waipio)

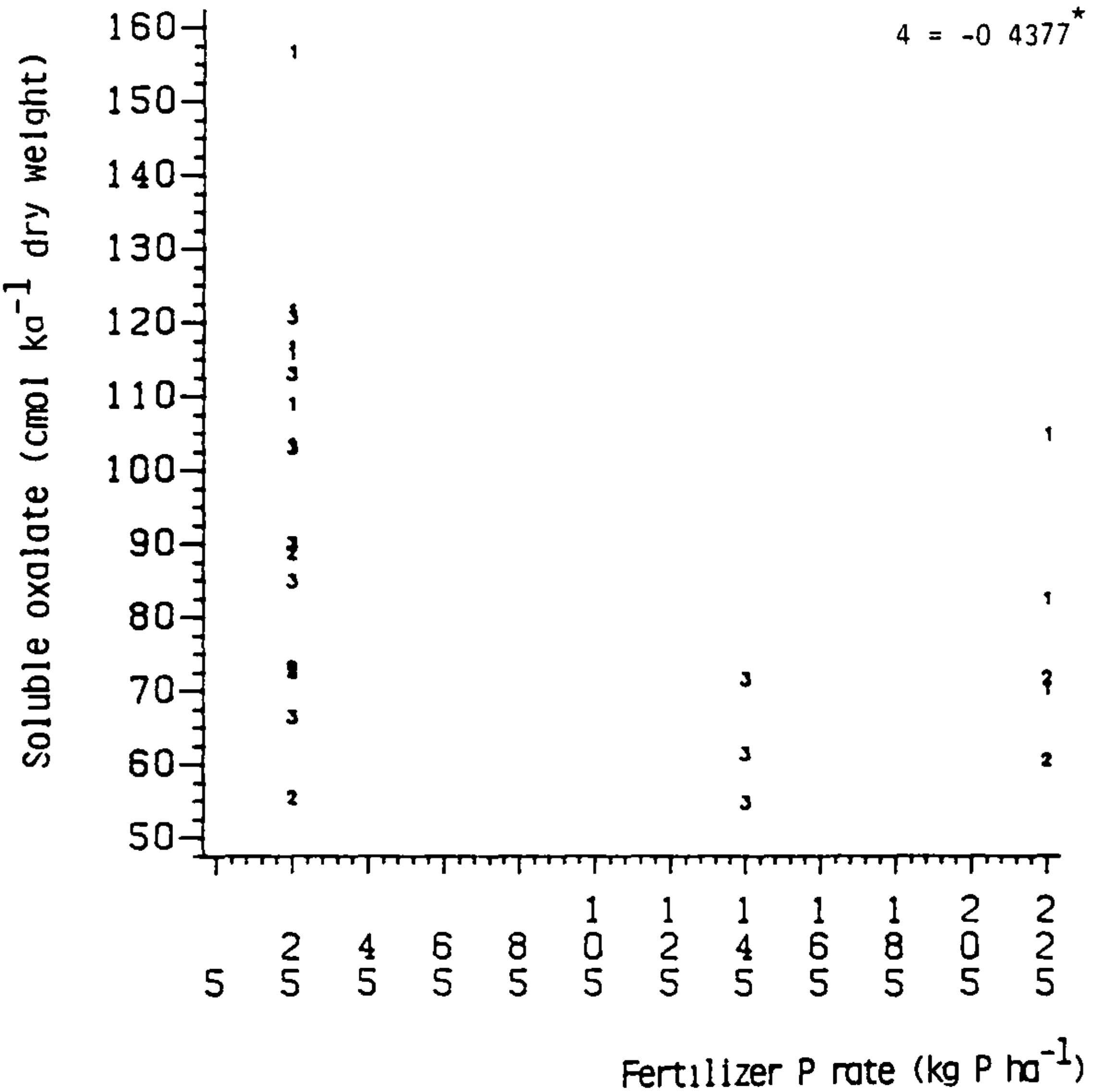


Figure 4 24 Relationship between tissue soluble oxalate of amaranth and fertilizer P rate from irrigated plots of experiments at three sites
(1=Kukaiau, 2=Iole, 3=Waipio)

Table 4 43

Multiple regression equation for insoluble oxalate concentration in amaranth from non-irrigated plots of three experimental sites

Variable*	Regression coefficient	Standard error	t	Probability > |t|
Intercept	135 991	8 8214	15 516	0 0001
SOLP	-0 5121	0 1386	-3 696	0 0011
PLEVEL	0 1659	0 0277	5 997	0 0001

Model r^2 = 0 6057
Model Adj r^2 = 0 5728

* SOLP = Soil P concentration
PLEVEL = Fertilizer P rate

the cation excess and therefore, oxalate production applies here as well The regression coefficient of fertilizer P rate was significantly positive which is consistent with the significant positive relationship between insoluble oxalate and fertilizer P rate (Figure 4 25) The additional Ca supplied to plants by P fertilizer probably led to high Ca oxalate content in plants receiving this treatment

The regression model for insoluble oxalate in irrigated plants is shown in Table 4 44 Seventy-five percent of the variance in insoluble oxalate was explained by this model in contrast to 57% for soluble oxalate in non-irrigated plants 55% for soluble oxalate in irrigated plants and 57% for insoluble oxalate in non-irrigated plants P-related variables were significantly related as were fertilizer N rate and average air temperature Fertilizer N rate was not

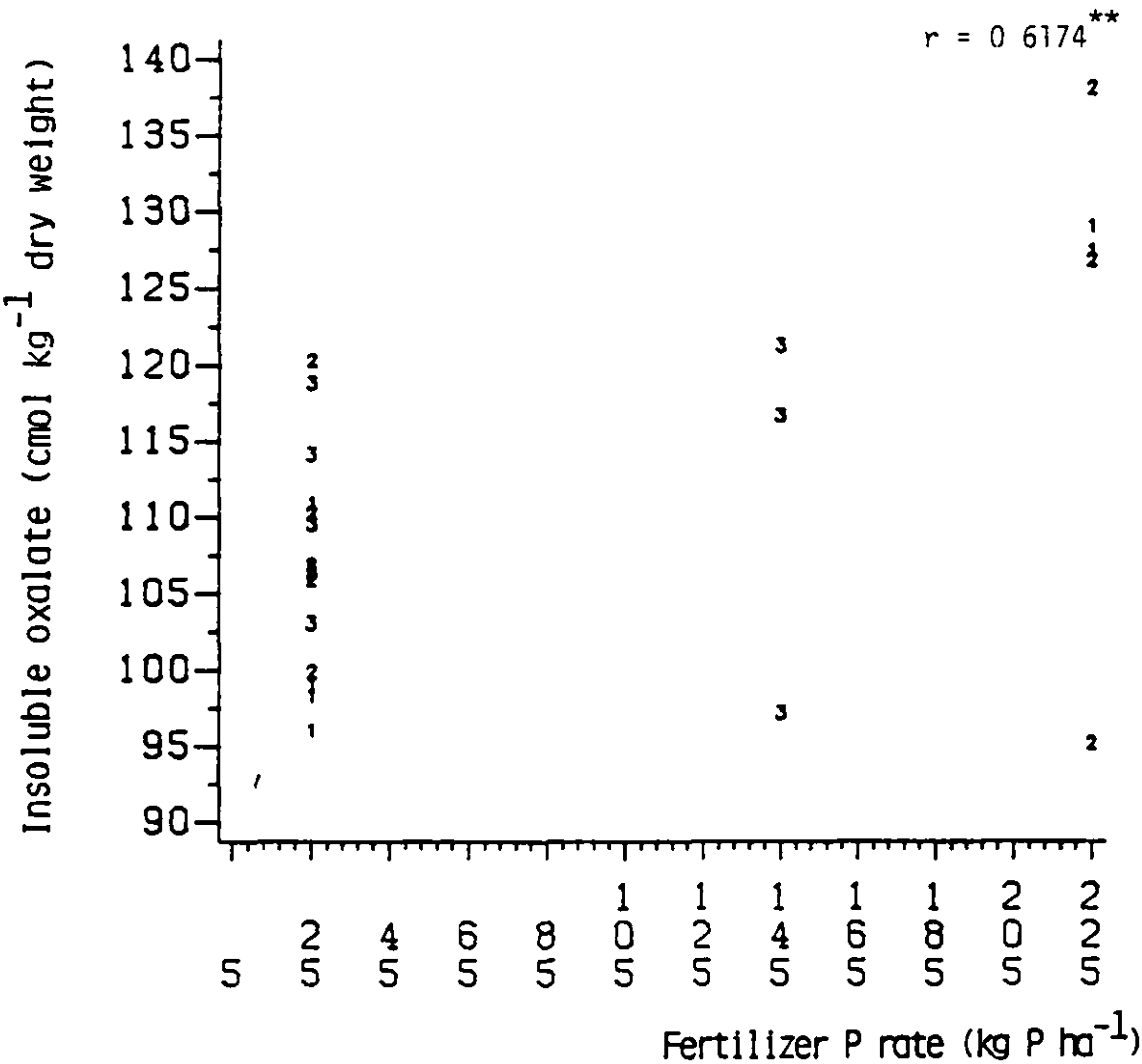


Figure 4 25 Relationship between tissue insoluble oxalate of amaranth and fertilizer P rate from non-irrigated plots of experiments at three sites (1=Kukaiau, 2=Iole 3=Waipio)

Table 4 44

Multiple regression equation for insoluble oxalate concentration in amaranth from irrigated plots of three experimental sites

Variable*	Regression coefficient	Standard error	t	Probability > |t|
Intercept	441 555	42 6866	10 346	0 0001
AIR3	-16 5982	2 0681	-8 026	0 0001
NLEVEL	0 0754	0 0295	2 552	0 0190
PLEVEL	0 0512	0 0335	1 528	0 1422

Model r^2 = 0 7840
Model Adj r^2 = 0 7516

* AIR3 = Average air temperature
NLEVEL = Fertilizer N rate
PLEVEL = Fertilizer P rate

significantly related with insoluble oxalate (Table 4 27) but the regression coefficient was significantly positive The role of N in organic acid synthesis in plants is well known The process of N assimilation leads to the synthesis of organic acid as shown for example by the study by Ikeda and Yamada (1981) For this regression average air temperature was negative as was the case for simple correlation (Figure 4 26)

The regression model for nitrate-N concentration in non-irrigated plants is shown in Table 4 45 Fertilizer N contributed most to explaining the variance in nitrate-N concentration The regression

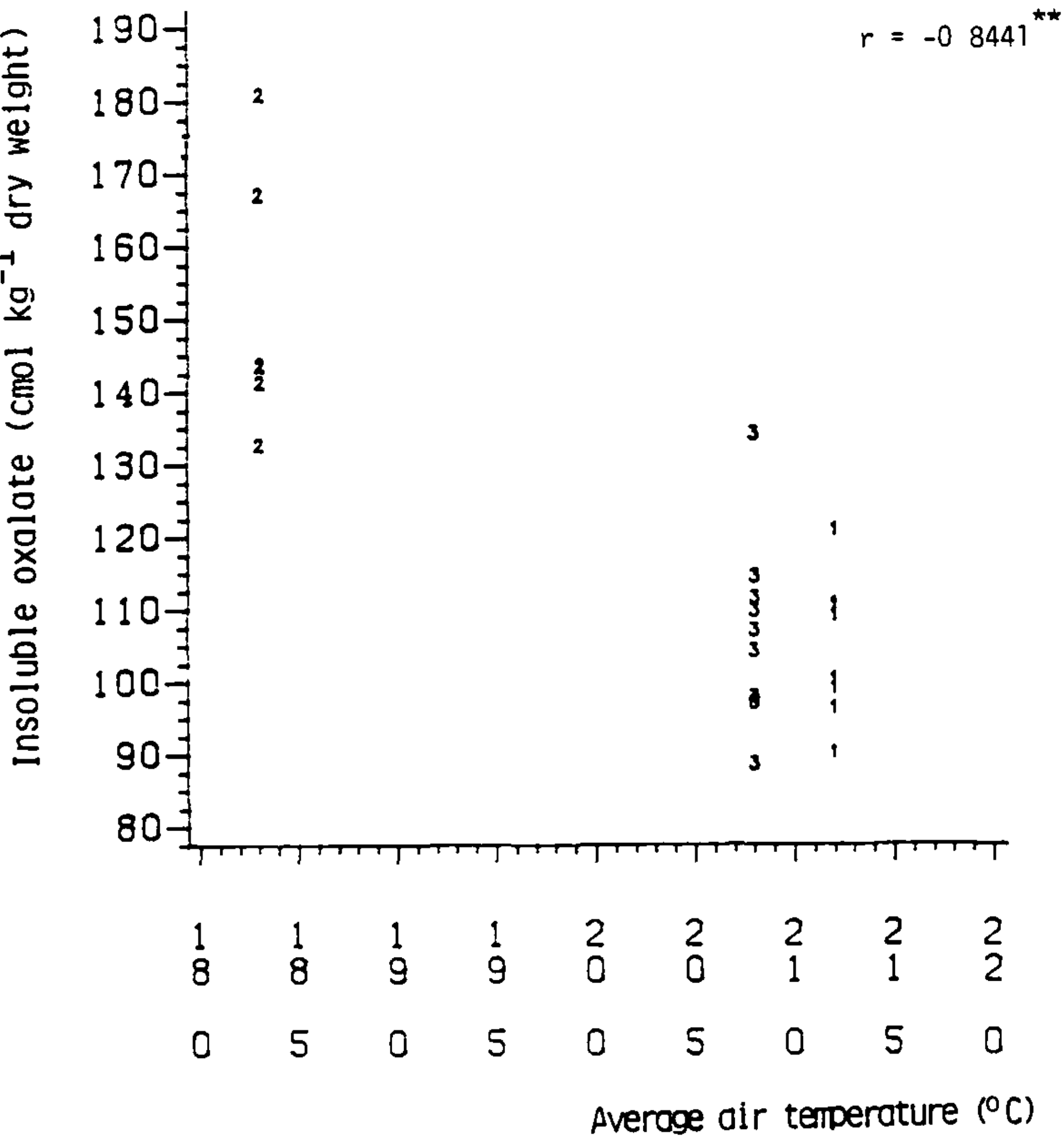


Figure 4 26 Relationship between tissue insoluble oxalate of amaranth and average air temperature from irrigated plots of experiments at three sites
(1=Kukaiau, 2=Iole, 3=Waipio)

Table 4 45

Multiple regression equation for nitrate-N concentration in amaranth from non-irrigated plots of three experimental sites

Variable*	Regression coefficient	Standard error	t	Probability > |t|
Intercept	39 8414	4 6198	8 624	0 0001
WSPSQ	-0 3053	0 2506	-1 218	0 2360
NLEVEL	0 0764	0 0164	4 657	0 0001
SOLMG	-18 5415	5 6715	-3 269	0 0035
SOLK	39 0297	18 5464	2 104	0 0470

Model r^2 = 0 7861

Model Adj r^2 = 0 7472

* WSPSQ = Square of wind speed

NLEVEL = Fertilizer N rate

SOLMG = Soil Mg concentration

SOLK = Soil K concentration

coefficient was positive, and consistent with the relationship between the two variables (Figure 4 27) Initial soil N did not significantly influence plant nitrate concentration probably due to its low level compared with applied fertilizer N The regression coefficient of the square of wind speed was negative in accordance with its negative relationship with nitrate-N (Figure 4 28) High wind speed usually increases transpiration rate According to Maynard et al (1976) transpiration also accelerates the translocation of nitrate to the site of reduction The regression coefficient of soil Mg was negative in

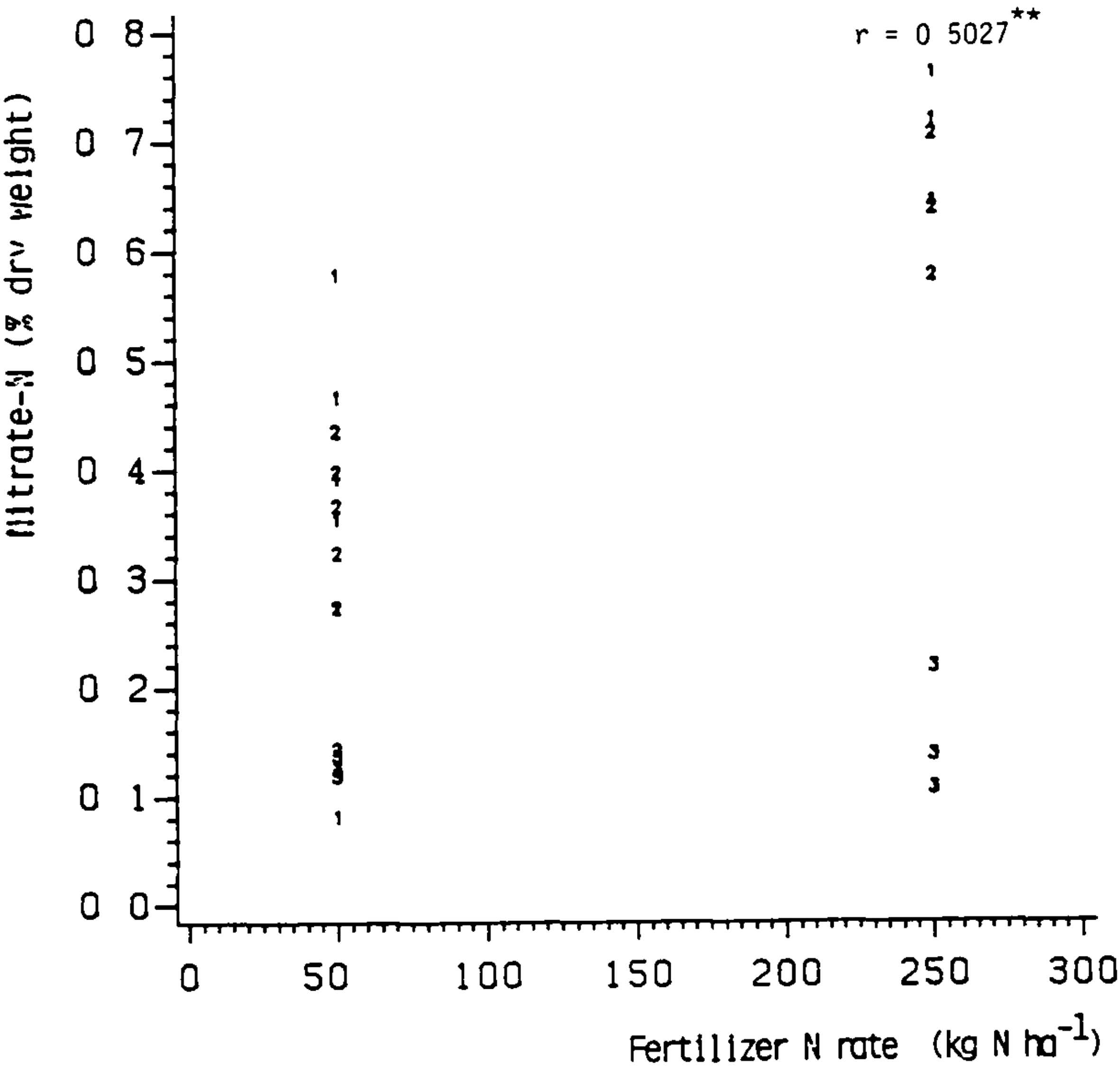


Figure 4 27 Relationship between tissue nitrate-N concentration of amaranth and fertilizer N rate from non-irrigated plots of experiments at three sites
(1=Kukaiau, 2=Iole, 3=Waipio)

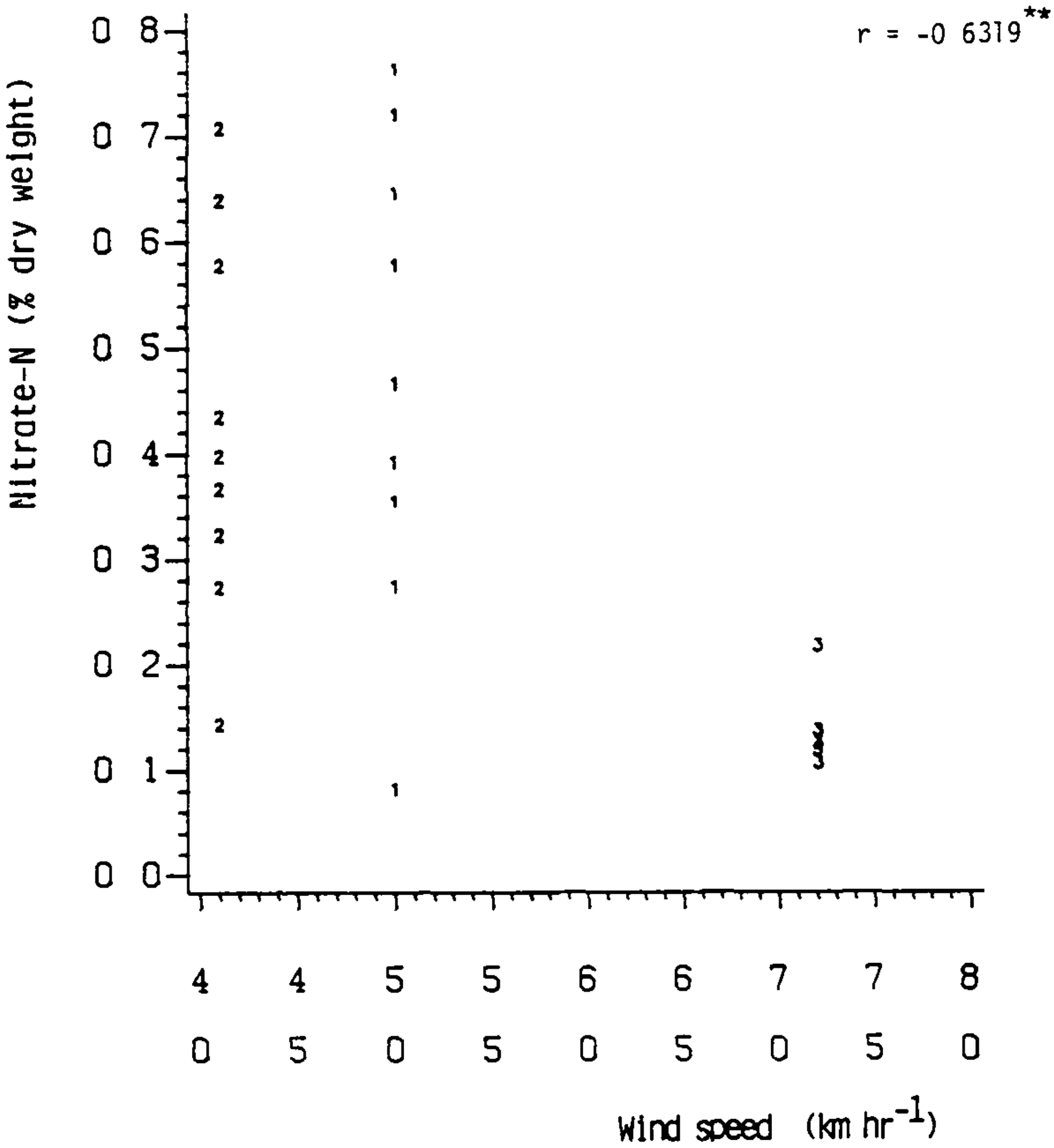


Figure 4 28 Relationship between tissue nitrate-N concentration of amaranth and wind speed from non-irrigated plots of experiments at three sites (1=Kukaiau, 2=Iole, 3=Waipio) accordance with its negative relationship with nitrate-N (Figure 4 29) On the other hand, the regression coefficient of soil K was positive despite its negative relationship with nitrate-N (Figure 4 30) The change in sign is probably due to the highly correlated nature of soil Mg and soil K (Appendix C) Moreover, K is often the cation accompanying nitrate movement from the root to the shoot (Minotti, 1968) K fertilizer also increased nitrate content in some vegetables (Cantliffe, 1973)

The results of the multiple regression analysis of nitrate-N concentration in irrigated amaranth are shown in Table 4 46 In addition to N fertilizer rate (Figure 4 31) and soil N (Figure 4 32), minimum air temperature also helped to explain the variance in the nitrate-N concentration Minimum air temperature was squared because it showed a curvilinear relationship with nitrate-N (Figure 4 33) The positive relationship between minimum air temperature and nitrate-N concentration shown in Figure 4 33 was apparent in the multiple regression analysis This is consistent with the observation that high temperatures increased plant nitrate content This effect was attributed to a combination of reduced nitrate reductase activity and higher availability of soil nitrate due to increased microbial activity

4 3 Response of cassava to environmental factors

In this section emphasis is placed on the results concerning the effects of environmental factors on nutrient and antinutrient contents of cassava leaves

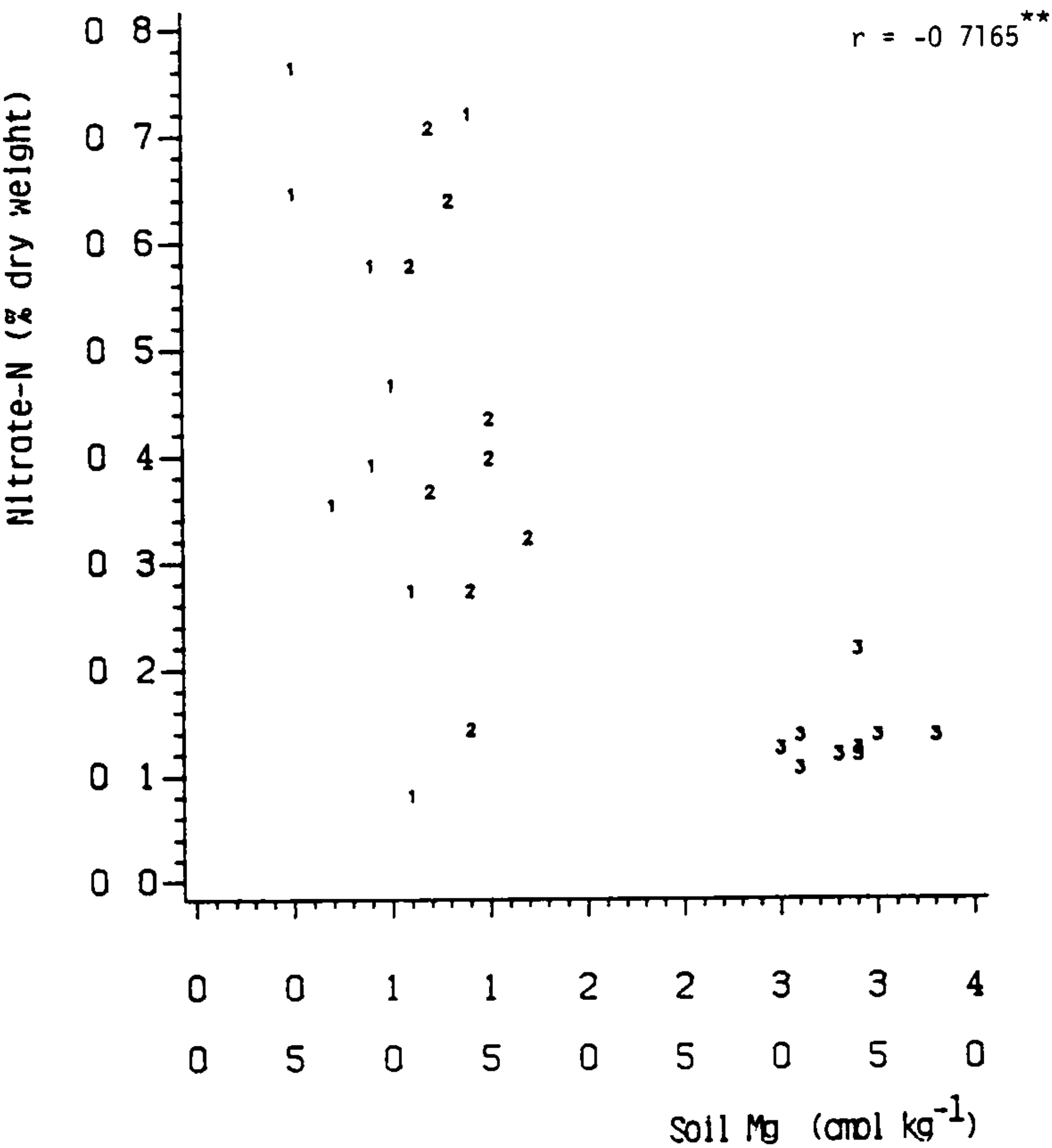


Figure 4 29 Relationship between tissue nitrate-N concentration of amaranth and soil Mg from non-irrigated plots of experiments at three sites
(1=Kukaiau, 2=Iole, 3=Waipio)

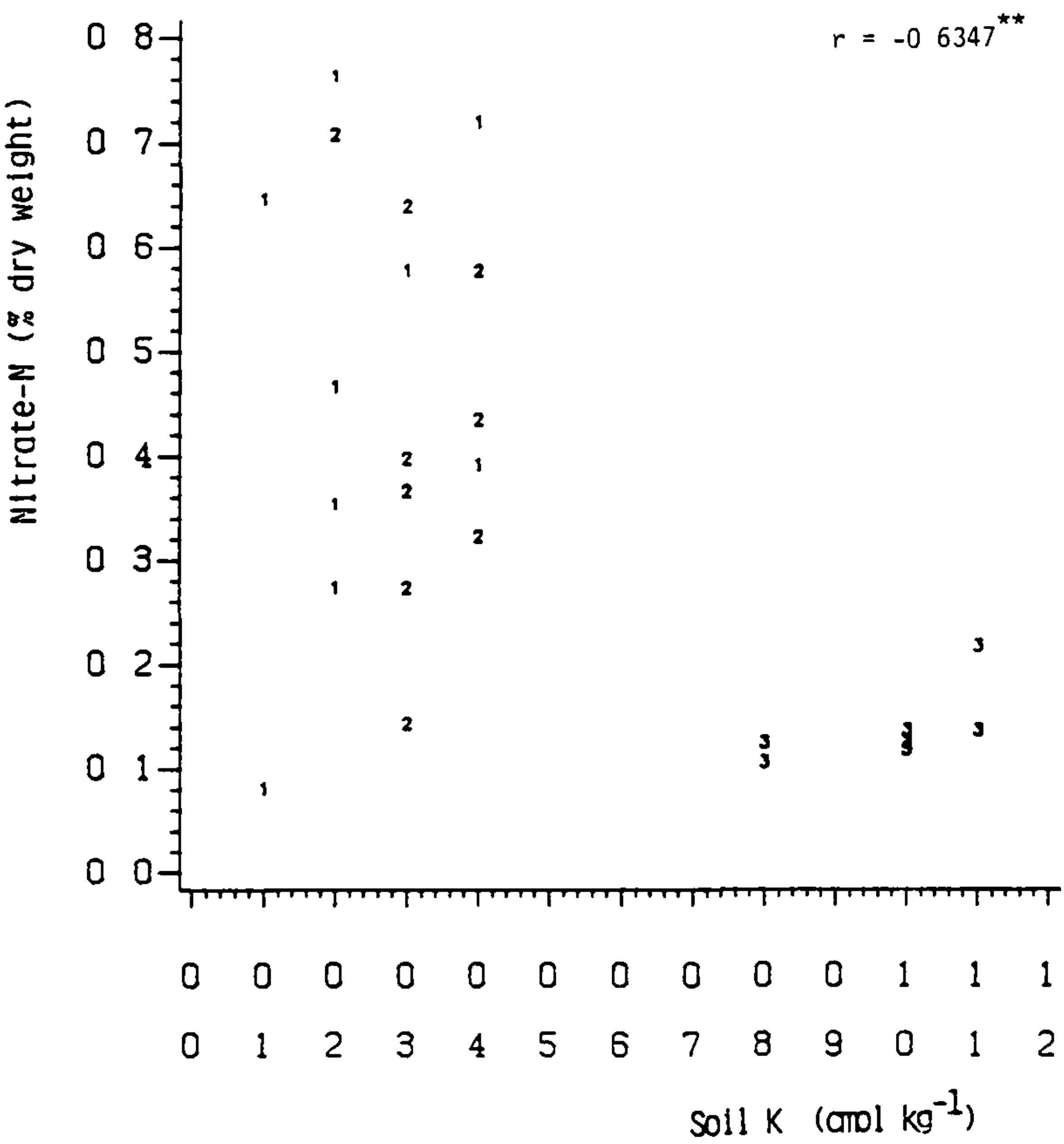


Figure 4 30 Relationship between tissue nitrate-N concentration of amaranth and soil K from non-irrigated plots of experiments at three sites
(1=Kukaiau, 2=Iole, 3=Waipio)

Table 4 46

Multiple regression equation for nitrate-N concentration in amaranth from irrigated plots of three experimental sites

Varaible*	Regression coefficient	Standard error	t	Probability > |t|
Intercept	-31 6711	10 4777	-3 023	0 0065
AIR2SQ	0 1377	0 0498	2 763	0 0116
NLEVEL	0 0603	0 0169	3 559	0 0019
SOLTN	27 4725	9 9755	2 754	0 0119

Model r^2 = 0 6595

Model Adj r^2 = 0 6108

* AIR2SQ = Square of minimum temperature

NLEVEL = Fertilizer N rate

SOLTN = Soil N concentration

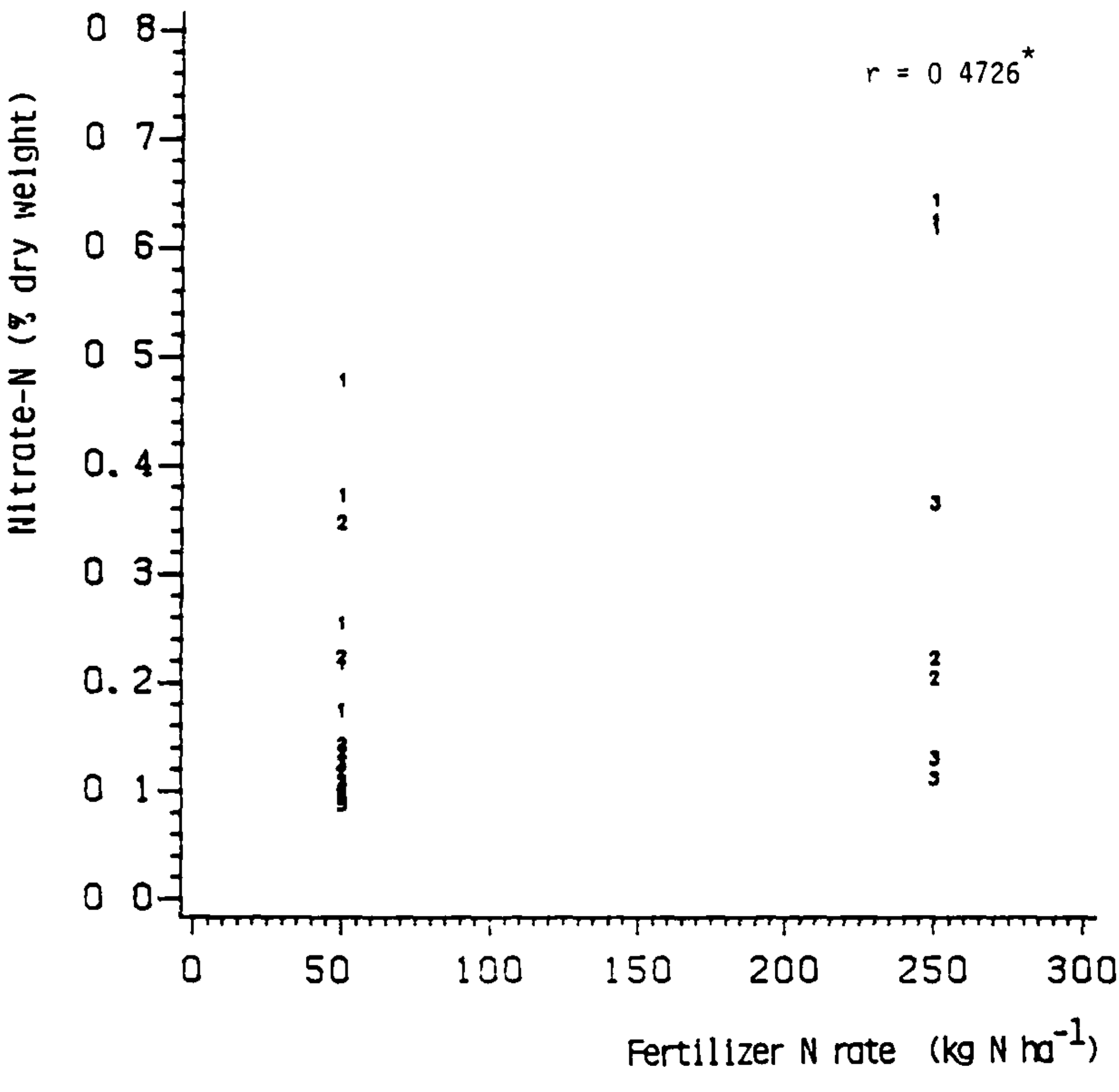


Figure 4 31 Relationship between tissue nitrate-N concentration of amaranth and fertilizer N rate from irrigated plots of experiments at three sites
(1=Kukaiau, 2=Iole, 3=Waipio)

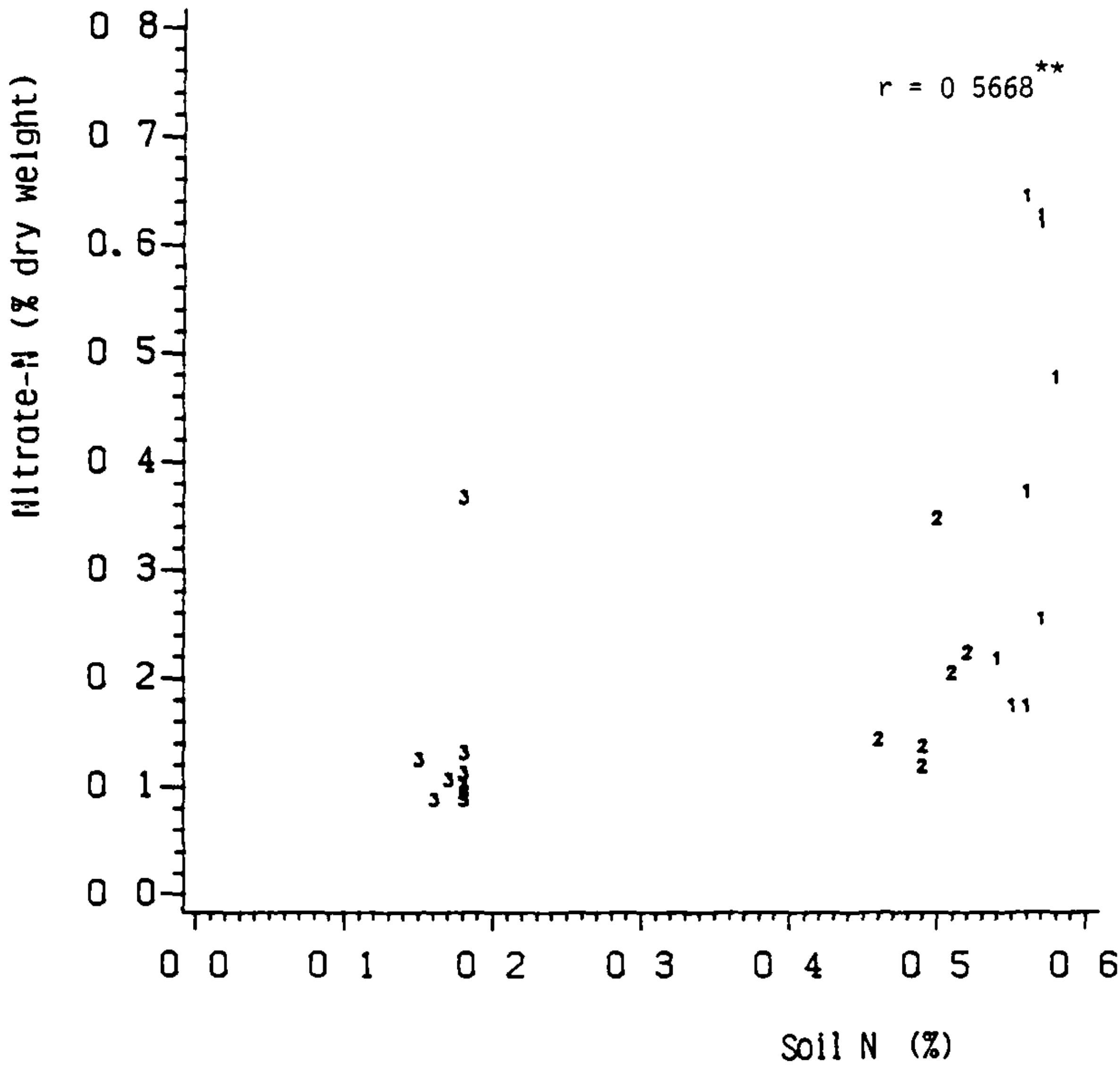


Figure 4 32 Relationship between tissue nitrate-N concentration of amaranth and soil N from irrigated plots of experiments at three sites
(1=Kukaiau, 2=Iole, 3=Waipio)

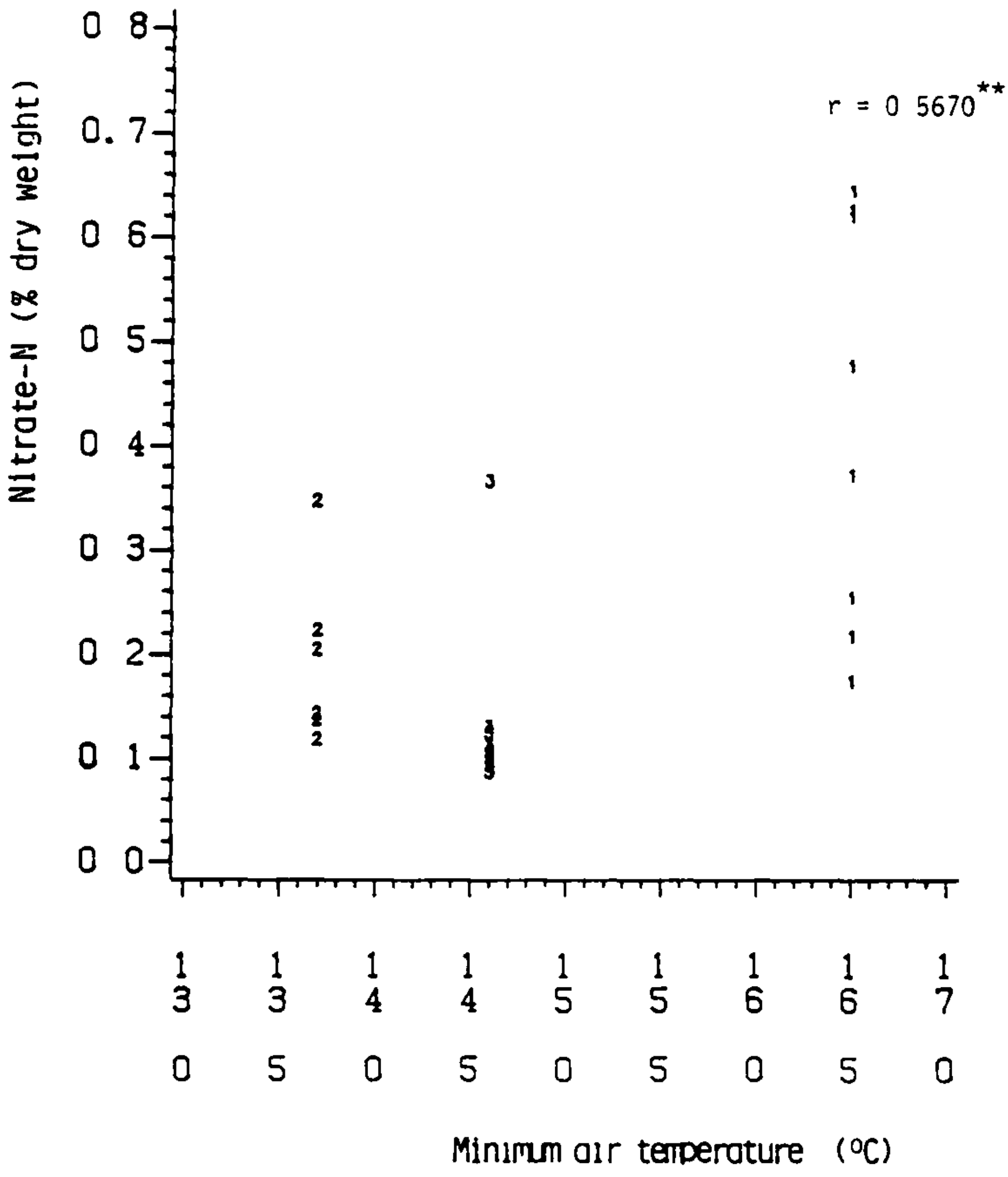


Figure 4 33 Relationship between tissue nitrate-N concentration of amaranth and minimum air temperature from irrigated plots of experiments at three sites
(1=Kukaiau, 2=Iole 3=Waipio)

4 3 1 Forms and content of oxalate in cassava leaves

The significant positive correlations between concentrations of total and insoluble oxalate and tissue Ca and Mg suggest that oxalate in cassava leaves was in the form of Ca oxalate or Mg oxalate or both However, the fact that total and insoluble oxalate had significant positive correlations only with Ca in the insoluble fraction (Table 4 47 Figures 4 34 4 35) and not with Mg (Table 4 47) suggests that oxalate in cassava was mostly in the form of Ca oxalate Another suggestion of the dominance of Ca oxalate over Mg oxalate is that the sum of Ca and Mg was not as well correlated with oxalates as Ca alone (Table 4 47)

Soluble oxalate was detected in only one sample from the Molokai non-irrigated plot which had a soluble oxalate content of 6 5 cmol kg^{-1} dry weight The insoluble oxalate concentration, from Molokai and Iole plants was consistently lower than total oxalate concentration (Appendix E) and consequently the difference between the two was taken as the soluble oxalate concentration (Table 4 48, Appendix E) Molokai plants had a relatively higher content of soluble oxalate than the plants from the other sites while Waipio plants had virtually no soluble oxalate (Table 4 48, Appendix E) It cannot be stated for certain from this study what form of soluble oxalate occurred in cassava leaves It probably was Mg or K oxalate or both Nevertheless, the fact that Waipio plants had significantly higher tissue Ca concentration and lower tissue K concentration than the plants from the other three sites (Table 4 49) probably accounts for the absence of soluble oxalate

Table 4 47

Correlation between oxalates and various cations in cassava leaves

	Correlation coefficients* (Probability > |r|)	
Element	Total oxalate	Insoluble oxalate
Tissue Ca	0 5883 (0 0064)	0 6444 (0 0022)
Mg	0 4222 (0 0637)	0 5898 (0 0062)
K	-0 1998 (0 3984)	-0 4482 (0 0475)
Na	-0 3700 (0 1083)	-0 2642 (0 2604)
Insoluble fraction Ca	0 6239 (0 0033)	0 7751 (0 0001)
Mg	-0 0141 (0 9529)	0 1935 (0 4138)
K	-0 3167 (0 1737)	-0 3785 (0 0998)
Na	0 7414 (0 0002)	0 7415 (0 0002)
Ca+Mg	0 5835 (0 0069)	0 7472 (0 0001)

* Number of observations = 20

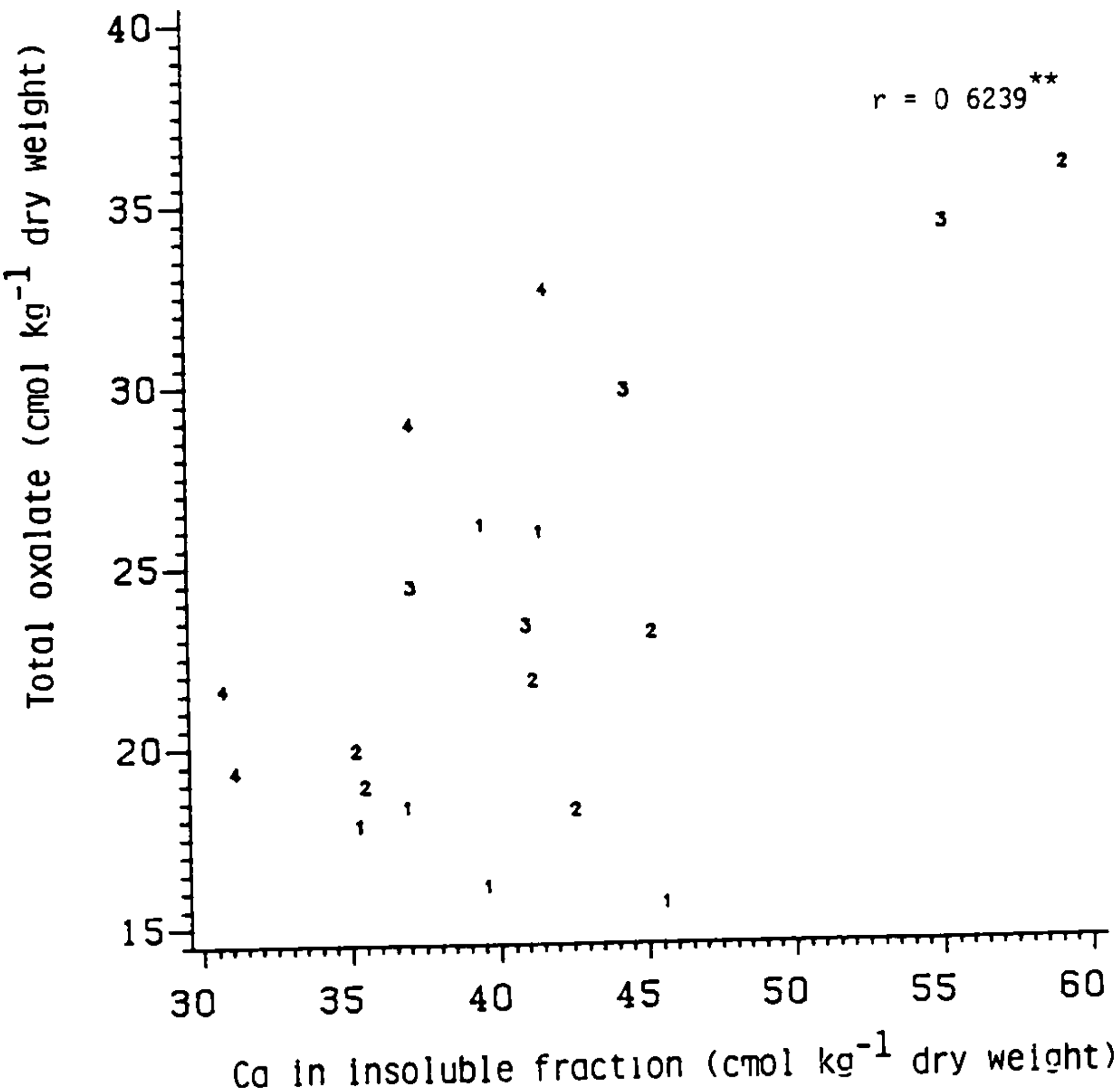


Figure 4 34 Relationship between total oxalate and Ca in the extract of insoluble oxalate fraction of leaf tissue of cassava grown at four sites (1=Kukaiau, 2=Iole 3=Waipio)

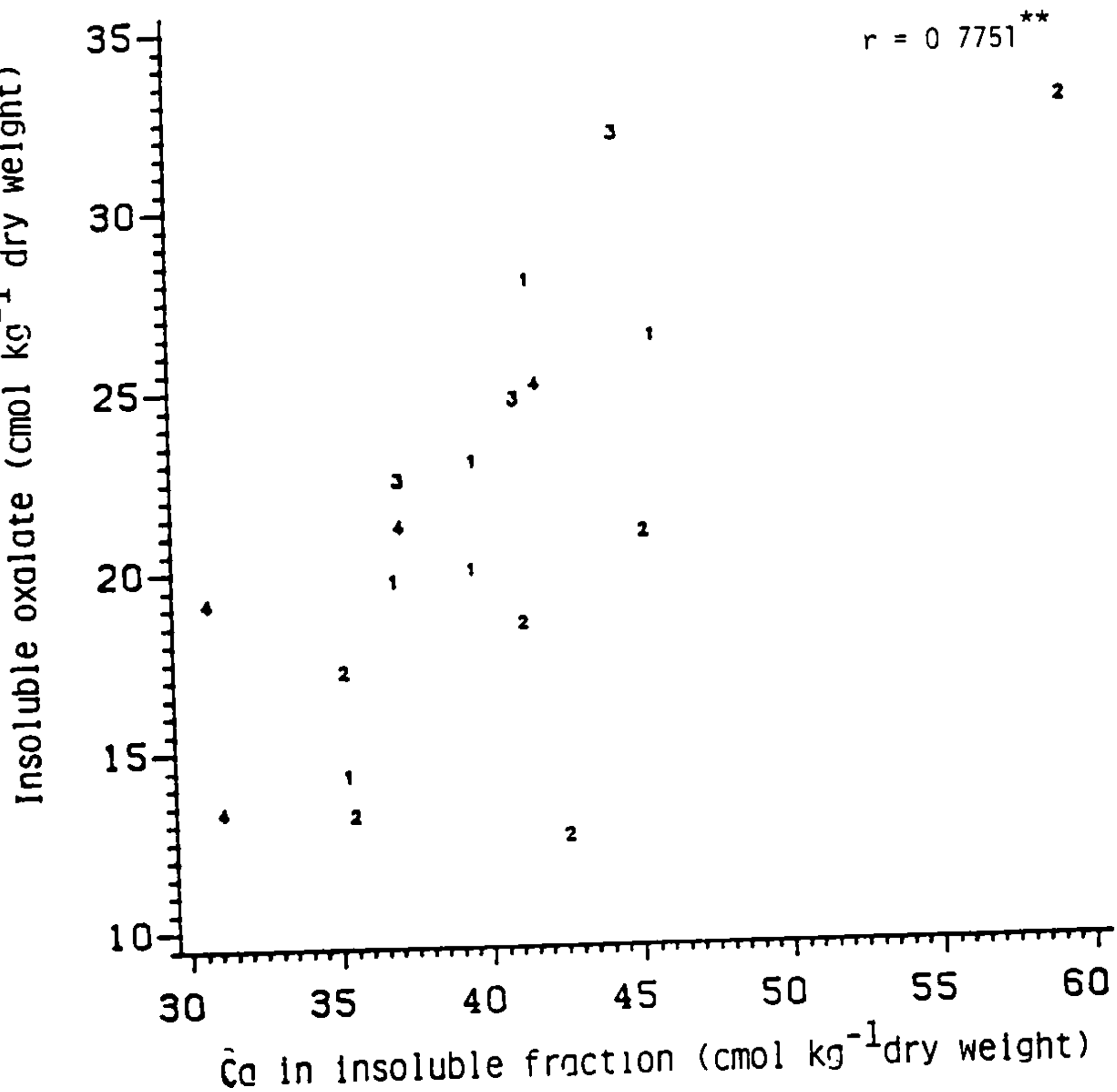


Figure 4 35 Relationship between insoluble oxalate and Ca in the extract of insoluble oxalate fraction of leaf tissue of cassava grown at four sites (1=Kukaiau, 2=Iole, 3=Waipio)

Table 4 48

Oxalate concentration in cassava leaf tissue of plant grown at four different sites

Site	Total oxalate	Insoluble oxalate	Soluble oxalate[d]
	(cmol kg^{-1} dry weight)		
Molokai	25 6 A[b]	19 7 B[b]	5 9
	(1 2)[c]		
Waipio	28 0[a] A	29 4 A	-
	(1 3)		
Iole	23 0 A	19 2 B	3 8
	(1 0)		
Kukaiau	20 0[a] A	21 9 AB	-
	(0 9)		

[a] Pair comparison using LSD show that the two means are significantly different (Probability > |t| = 0 0464)

[b] Means in the same column followed by the same capital letter are not significantly different at 0 05 probability level (Waller-Duncan's multiple range test)

[c] Oxalate concentration in the unit of % on a dry weight basis

[d] Soluble oxalate was obtained by subtracting insoluble oxalate from total oxalate

in Waipio plants and that if soluble oxalate did occur it would do so in the form of K oxalate

The content of total oxalate in cassava leaves ranges from 0 9-1 3% on a dry weight basis (Table 4 48) This range was considerably less than that in amaranth

4 3 2 Chemical compositions of plants grown at different sites

Waipio plants had higher concentrations of total and insoluble oxalates than the plants from the other sites (Table 4 48) For Waipio plants, the results showed that all oxalate was in the forms of insoluble oxalate while some soluble oxalate occurred in plants from Molokai and Iole (Table 4 48) The higher Ca concentration in Waipio plants (Table 4 49) probably led to the higher Ca oxalate concentration in these plants The relatively higher K concentrations in plants from the Molokai and Iole sites (Table 4 49) probably led to the occurrence of small quantities of soluble oxalate

It appears that the oxalate form was determined by the dominant cations in the plants Ca was the dominant cation in plants from Waipio (Table 4 49), which probably resulted in Ca oxalate being the primary form of oxalate Molokai and Iole plants had about equal concentrations of Ca and K which may have promoted the formation of K oxalate although Ca oxalate was still dominant

Relationship between oxalate concentrations and cation excess

Oxalate constituted only 18 6-25 9% of the cation excess in cassava leaves (Table 4 51) It is probable that oxalate was not the dominant organic acid in cassava This is different from amaranth in which more than 60% of cation excess was accounted for by oxalate

Table 4 49

Ionic concentrations and cation excess contents in cassava grown at four experimental sites

Site	Ca	Mg	K	Na	SC[a]	P	S	NO_3	Cl	SA[b]	C-A
	(cmol kg^{-1} dry weight)										
Molokai	53 6 B[c]	18 8 B[c]	49 7 A[c]	1 5 A[c]	123 6 A[c]	3 6 B[c]	5 2 B[c]	7 7 A[c]	5 8 A[c]	22 2 A[c]	101 4 A[c]
	(1 1)[d]	(0 2)	(1 8)	(0 03		(0 3)	(0 2)		(0 20)		
Waipio	63 9 A	22 7 A	42 7 B	1 2 C	130 2 A	3 9 B	4 8 C	7 8 A	5 8 A	22 2 A	108 1 A
	(1 3)	(0 3)	(1 7)	(0 03)		(0 4)	(0 2)		(0 19)		
Iole	54 4 AB	18 9 B	50 2 A	1 3 BC	124 9 A	5 6 A	5 5 A	2 9 C	4 7 B	18 6 B	106 3 A
	(1 1)	(0 2)	(2 0)	(0 03)		(0 5)	(0 3)		(0 17)		
Kukaiau	55 8 AB	18 6 B	50 5 A	1 6 A	126 5 A	4 2 B	5 2 B	4 9 B	4 9 AB	19 2 B	107 4 A
	(1 1)	(0 2)	(2 0)	(0 04)		(0 4)	(0 2)		(0 17)		

[a]Sum of cations

[b]Sum of anions

[c]Means of each ion with the same capital letter are not significantly different at 0 05 probability level (Waller-Duncan's multiple range test)

[d]Ionic concentrations in the unit of % on a dry weight basis

Table 4 50

Insoluble oxalate and calcium concentrations in cassava grown at four sites

Site	Insoluble oxalate	Tissue Ca	Ca in the form of Ca oxalate
	——(cmol kg^{-1} dry weight)——		(% tissue Ca)
Molokai	19 7	53 6	37
Waipio	29 4	63 6	46
Iole	19 2	54 4	35
Kukaiau	21 9	55 8	39

Total oxalate was positively correlated with cation excess (Figure 4 36) Oxalate exhibited a higher positive correlation with Ca than with cation excess, therefore, it can be said that oxalate was more closely related with Ca concentration than with cation excess Since oxalate was probably not the primary organic acid in cassava, the lack of a significant response to cation excess was not surprising It might very well be that in cassava total organic acid responded to cation excess, whereas, oxalate responded to Ca The literature is not consistent with regard to the relationship between oxalate synthesis and Ca absorption Olsen (1939) and Rasmussen and Smith (1961) reported a positive relationship between Ca and oxalic acid in some plants On the other hand Osmond (1967) found no relationship between oxalate synthesis and Ca absorption in *Atriplex* He also found that oxalate content correlated with cation content rather than Ca alone

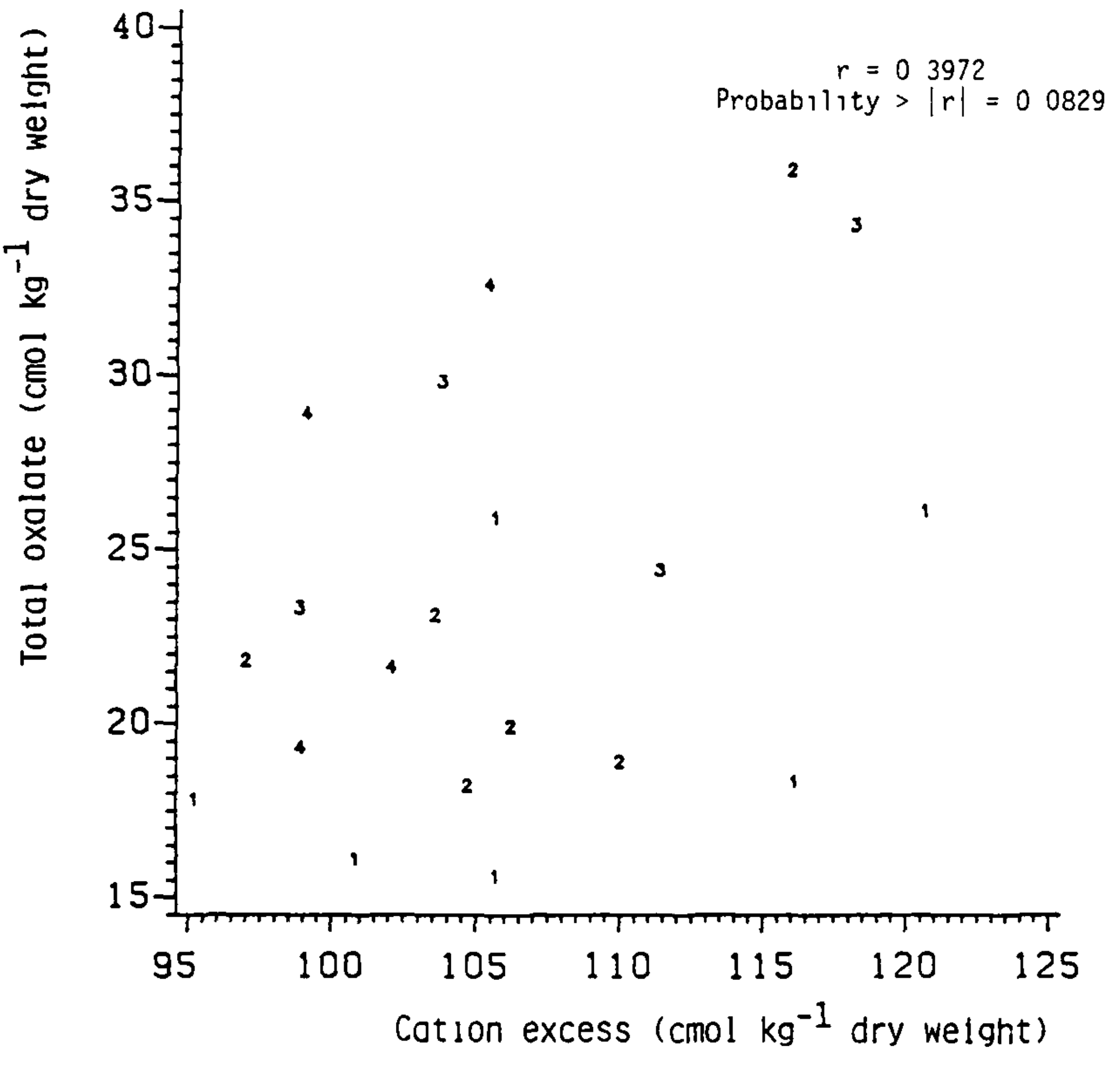


Figure 4 36 Relationship between total oxalate concentration and cation excess in leaf tissue of cassava grown at four sites
(1=Kukaiau, 2=Iole 3=Waipio)

Table 4 51

Oxalate content as percentage of cation excess (C-A) in cassava leaves

Site	Total oxalate	Cation excess	Total oxalate (% C-A)
	(cmol kg^{-1} dry weight)		
Molokai	25 6	101 4	25 2
Waipio	28 0	108 1	25 9
Iole	23 0	106 3	21 6
Kukaiau	20 0	107 4	18 6

Total N and nitrate-N concentrations and crude protein content

Higher total N and crude protein contents occurred in plants grown at the Hydric Dystrandept sites than at the Tropeptic Eutrustox sites (Table 4 52) This also occurred in amaranth plants and can be attributed to the higher soil N content in Hydric Dystrandept soils On the other hand, nitrate-N was significantly higher in plants grown in the Tropeptic Eutrustox than in plants from the Hydric Dystrandept sites The reason behind the higher nitrate-N in Tropeptic Eutrustox plants despite the lower soil N may be due to the climatic effects on nitrate assimilation Nitrate concentration was positively correlated with air and soil temperatures (Table 4 57) High temperature can decrease the nitrate reductase activity which results in the accumulation of nitrate (Cantliffe 1972a) The different results for nitrate-N between amaranth and cassava may also be caused by differences in rooting depth and length of growing period Cassava roots permeate

Table 4 52

Total N, nitrate-N and crude protein contents in the leaves of cassava grown at four sites

Site	Total N*	Nitrate-N*	Crude protein*
	(% dry weight)		
Molokai	4 60 B	0 11 A	28 8 B
Waipio	4 29 C	0 11 A	26 8 C
Iole	5 18 A	0 04 C	32 4 A
Kukaiau	4 72 B	0 07 B	29 5 B

* Means in the same column followed by the same letter are not significantly different at 0 05 probability level (Waller-Duncan s multiple range test)

a larger volume of soil for a longer period of time than do amaranth roots Nitrate-N found in cassava leaves in this study is not considered high and did not present a health hazard

Crude protein content of cassava leaves was 26 8-32 4% on a dry weight basis This is in the high range of protein content reported in the literature (Rogers and Milner 1963)

4 3 3 Effects of irrigation on chemical composition of plants grown at Molokai and Waipio sites

Significantly higher total and insoluble oxalates were in non-irrigated plants at Molokai but not at Waipio (Table 4 53) Both Molokai and Waipio are considered dry sites but Molokai was even drier than Waipio as shown by the nearly two-fold less precipitation received at Molokai (Table 3 21)

Total N concentration was significantly lower in non-irrigated plants at Molokai (Table 4 54) Nitrate-N concentrations were not affected by irrigation

Table 4 53

Effect of irrigation on oxalate concentration of taro grown at Molokai and Waipio

	Site			
	Molokai		Waipio	
	Total oxalate	Insoluble oxalate	Total oxalate	Insoluble oxalate
Irrigation*	cmol kg^{-1} dry weight			
NI	45 9	39 5	31 8	25 6
I	25 6	19 7	28 0	29 4
Probability > |F|	0 0426	0 0030	0 3792	0 4516

* NI = Non-irrigated I = Irrigated

4 3 4 Influence of plant soil and climatic factors on oxalate and nitrate concentrations

Insoluble oxalate concentrations were negatively correlated with total N but positively correlated with nitrate-N (Table 4 55) The negative relationship between oxalates and total N was rather surprising because nitrogen metabolism usually promotes the synthesis of oxalate Total N was negatively correlated with tissue Ca (Figure 4 37) This

Table 4 54

Effect of irrigation on total N and nitrate-N concentrations in taro grown at Molokai and Waipio

	Site			
	Molokai		Waipio	
	Total N	Nitrate-N	Total N	Nitrate-N
Irrigation*	% dry weight			
NI	4 08	0 11	4 30	0 10
I	4 60	0 11	4 29	0 11
Probability > |F|	0 0045	0 7718	0 9213	0 0887

* NI = Non-irrigated,   I = Irrigated

Table 4 55

Correlation between oxalates and total N and nitrate-N in cassava leaves grown at four sites

	Correlation coefficient* (Probability > |r|)	
Oxalate	Total N	Nitrate-N
Total	-0 4129 (0 0704)	0 4317 (0 0574)
Insoluble	-0 6393 (0 0024)	0 4082 (0 0740)

*Number of observations = 20

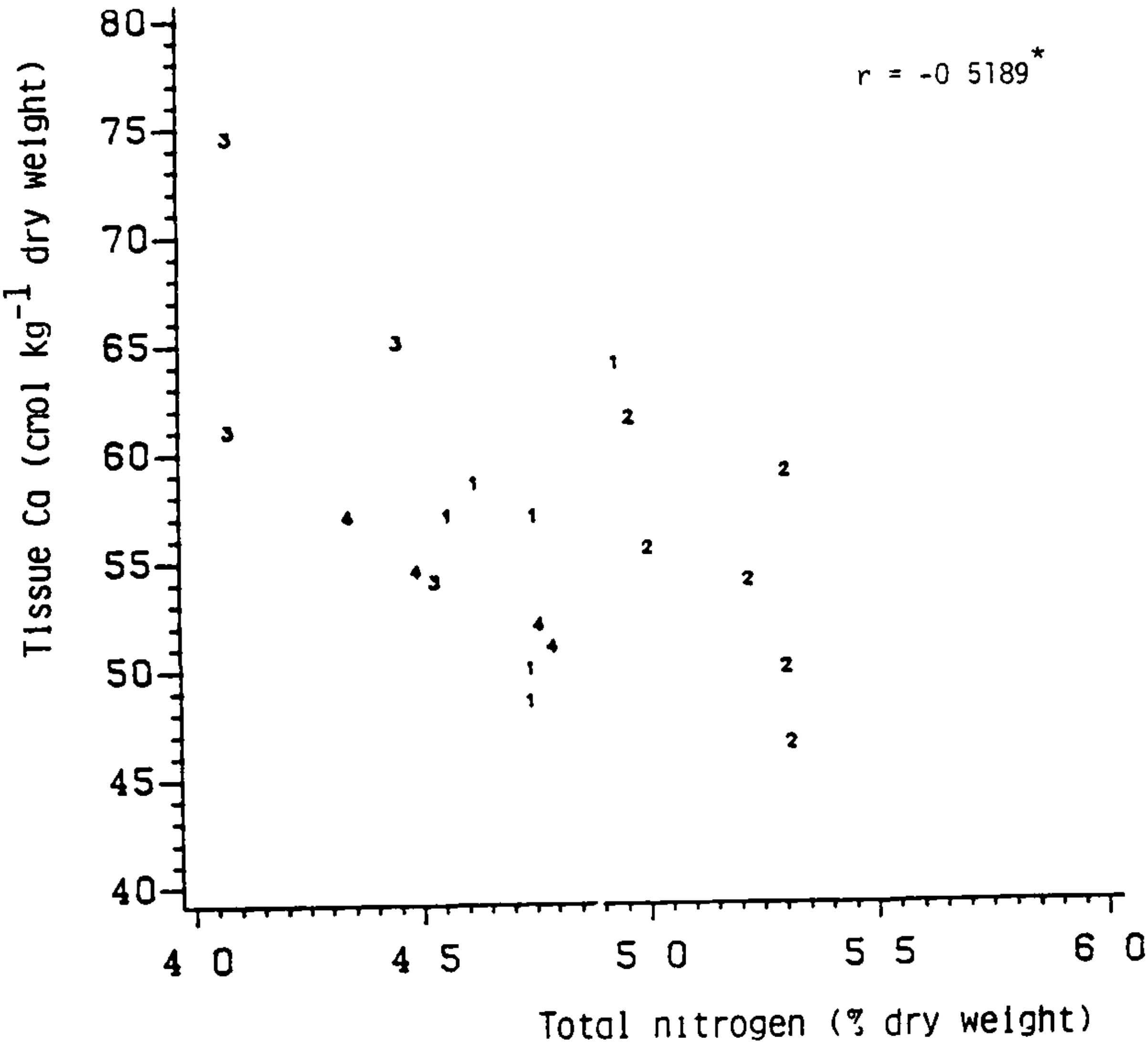


Figure 4 37 Relationship between Ca and total N concentration in leaf tissue of cassava grown at four experimental sites (1=Kukaiau, 2=Iole, 3=Waipio) suggests that total N and Ca are also correlated and therefore the relationship between total N and oxalates may not be a causal one

Oxalate and nitrate were positively correlated with soil cations while nitrate was negatively correlated with soil P (Table 4 56) The uptake of cations can increase the cation excess in plants which, in turn, leads to the synthesis of organic acid

Table 4 56

Correlation between oxalate in cassava and soil variables from four sites

Soil variables	Correlation coefficients* (Probability > |r|)		
	Total oxalate	Insoluble oxalate	Nitrate
Soil Ca	ns**	ns	ns
Mg	0 4727 (0 0353)	0 4400 (0 0522)	0 6243 (0 0033)
K	0 4743 (0 0346)	ns	0 7148 (0 0004)
Na	0 4528 (0 0450)	ns	0 8190 (0 0001)
P	ns	ns	-0 4745 (0 0345)

* Number of observations = 20
** ns = non-significant

The positive correlations between temperature and oxalates (Table 4 57) in cassava were different from the relationship found in amaranth Kitchen et al (1964b) postulated that in spinach oxalate

Table 4 57

Correlation between oxalate and nitrate in cassava with some climatic variables from four sites

Climatic variable	Correlation coefficient* (Probability > |r|)		
	Total oxalate	Insoluble oxalate	Nitrate-N
Average air temperature	ns**	ns	0 8510 (0 0001)
Average relative humidity	ns	-0 4581 (0 0422)	ns
Average topsoil temperature	ns	0 4701 (0 0365)	0 7362 (0 0002)
Average subsoil temperature	0 4626 (0 0400)	0 4481 (0 0475)	0 7198 (0 0003)
Rainfall	-0 4583 (0 0421)	ns	-0 6953 (0 0007)
Radiation	ns	ns	0 8485 (0 0001)
Wind speed	ns	ns	ns

* Number of observations = 20
** ns = non-significant

was used as a substrate for respiration at high temperature The positive correlations of nitrate with temperature and radiation were also found in amaranth Cantliffe (1972a) and Maynard et al (1976) found similar relations in other plants

4 4 Response of taro to environmental factors

As in the case with the section on cassava, this section emphasizes the results concerning the effects of environmental factors on nutrient and antinutrient contents of taro leaves

4 4 1 Forms of oxalate in taro

Taro contained both soluble and insoluble oxalates in contrast to cassava where most oxalate was in the insoluble form The positive correlation between insoluble oxalate and Ca (Table 4 58, Figure 4 38) suggests that insoluble oxalate was primarily Ca oxalate Moreover, the higher correlation of Ca plus Mg concentrations with insoluble oxalate (Table 4 58 Figure 4 39) suggests that a part of the insoluble oxalate was in the form of Mg oxalate

There was a positive correlation between both tissue K and K in the soluble oxalate fraction with soluble oxalate (Table 4 58 Figure 4 40) This suggests that the soluble oxalate was primarily K oxalate Mg oxalate probably constituted a significant part of soluble oxalate as suggested by high correlation where Mg was also considered r = 0 7898 (Table 4 58) The correlation between K+Mg in the soluble fraction and soluble oxalate was highly significant (Figure 4 41) suggesting that K and Mg oxalate were important constituents in taro

Table 4 58

Correlation between oxalates and mineral concentration in taro leaves

Element		Correlation coefficient* (Probability > |r|) Soluble oxalate	Insoluble oxalate	Soluble+Insoluble oxalate
Tissue	Ca	-0 7881 (0 0001)	0 3282 (0 0053)	ns
	Mg	ns**	ns	0 3435 (0 0323)
	K	0 6931 (0 0001)	ns	0 3412 (0 0335)
	Na	-0 5675 (0 0002)	0 3526 (0 0277)	ns
Soluble fraction	Ca	-0 6012 (0 0001)	ns	ns
	Mg	0 4531 (0 0038)	ns	0 4240 (0 0071)
	K	0 6712 (0 0001)	ns	ns
	Na	ns	ns	ns
	K+Mg	0 7898 (0 0001)	ns	-
Insoluble fraction	Ca	-0 7637 (0 0001)	0 4755 (0 0022)	ns
	Mg	ns	0 3741 (0 0190)	0 4652 (0 0028)
	K	0 3415 (0 0334)	-0 3201 (0 0470)	ns
	Na	-0 6858 (0 0001)	0 3360 (0 0365)	ns
	Ca+Mg	-0 7270 (0 0001)	0 5036 (0 0001)	ns

* Number of observations = 42
** ns = Non-significant

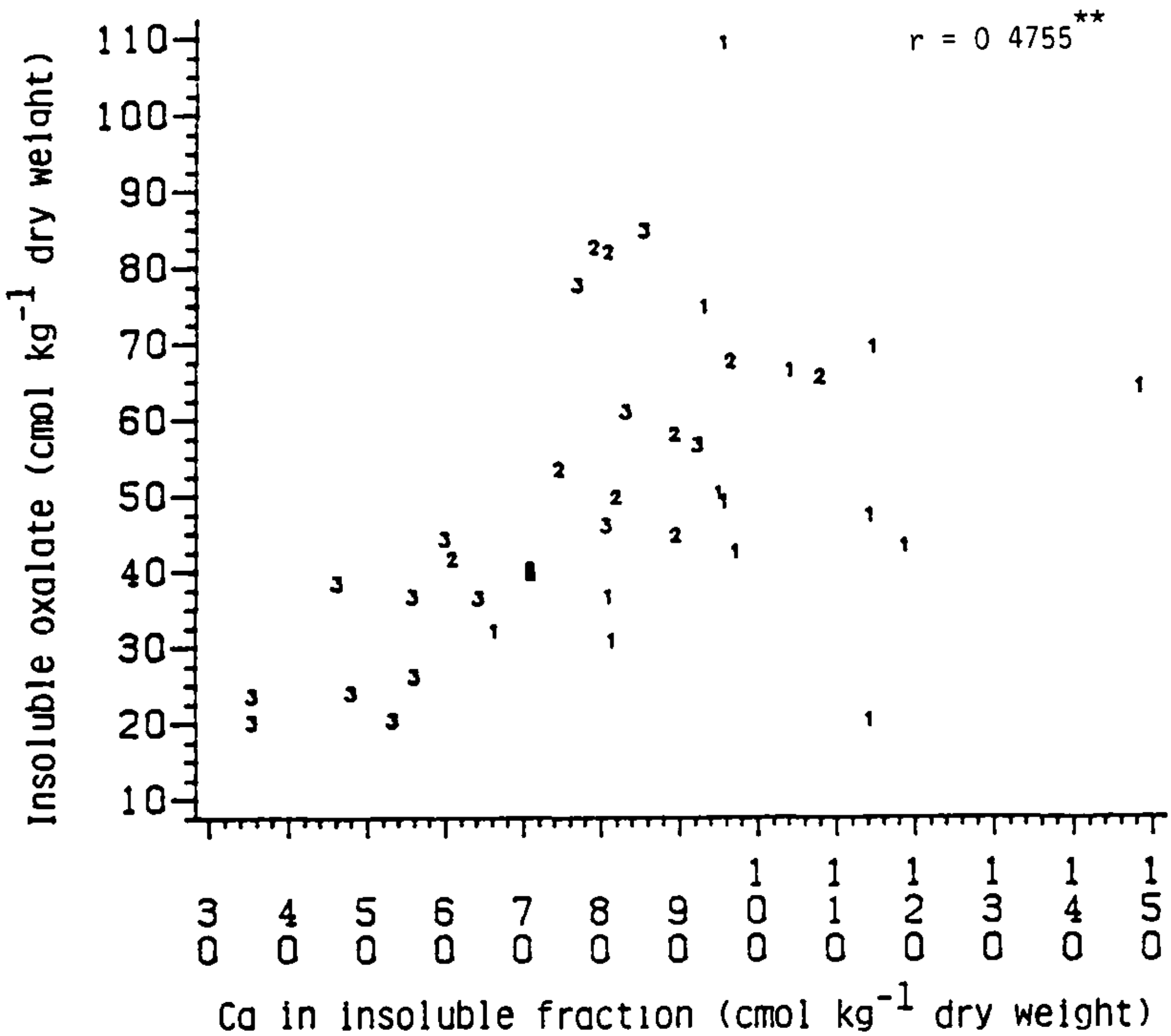


Figure 4 38 Relationship between insoluble oxalate and calcium in the extract of insoluble oxalate fraction of leaf tissue of taro grown at three sites (1=Kukaiau, 2=Iole, 3=Waipio)

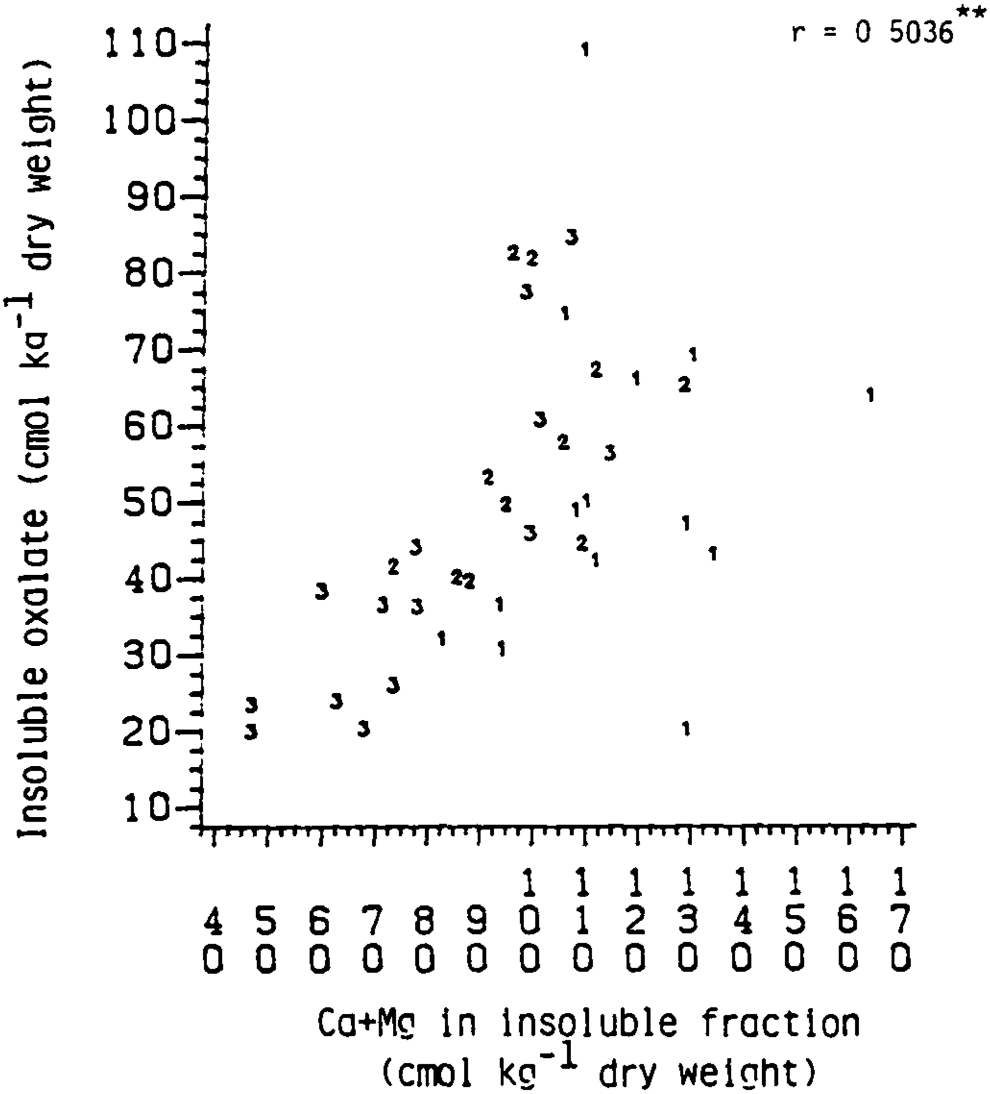


Figure 4 39 Relationship between insoluble oxalate and the sum of calcium and magnesium concentration in the extract of insoluble oxalate fraction of leaf tissue of taro grown at three sites (1=Kukaiau, 2=Iole, 3=Waipio)

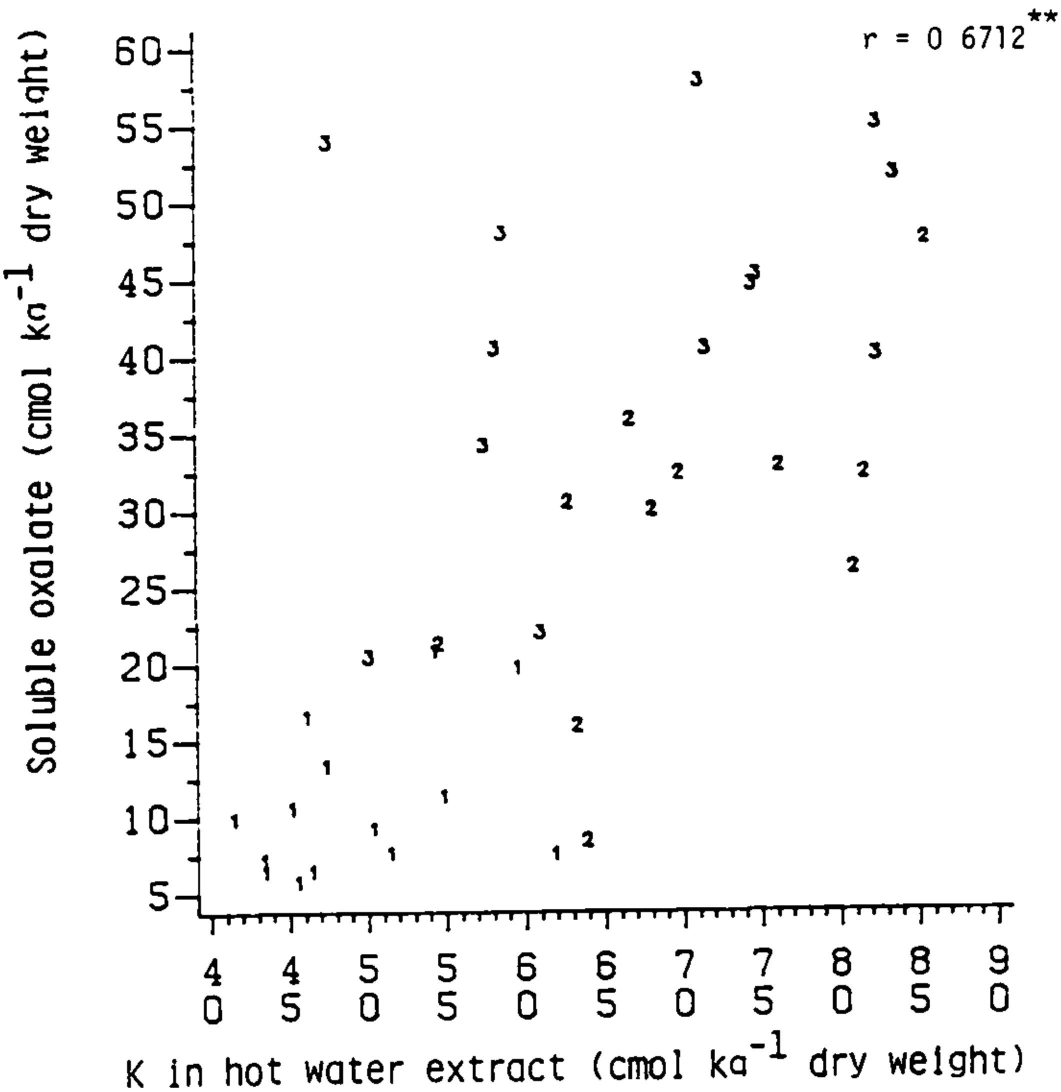


Figure 4 40 Relationship between soluble oxalate and potassium concentration in the extract of soluble oxalate fraction (hot water extract) of leaf tissue of taro grown at three sites
(1=Kukaiau, 2=Iole 3=Waipio)

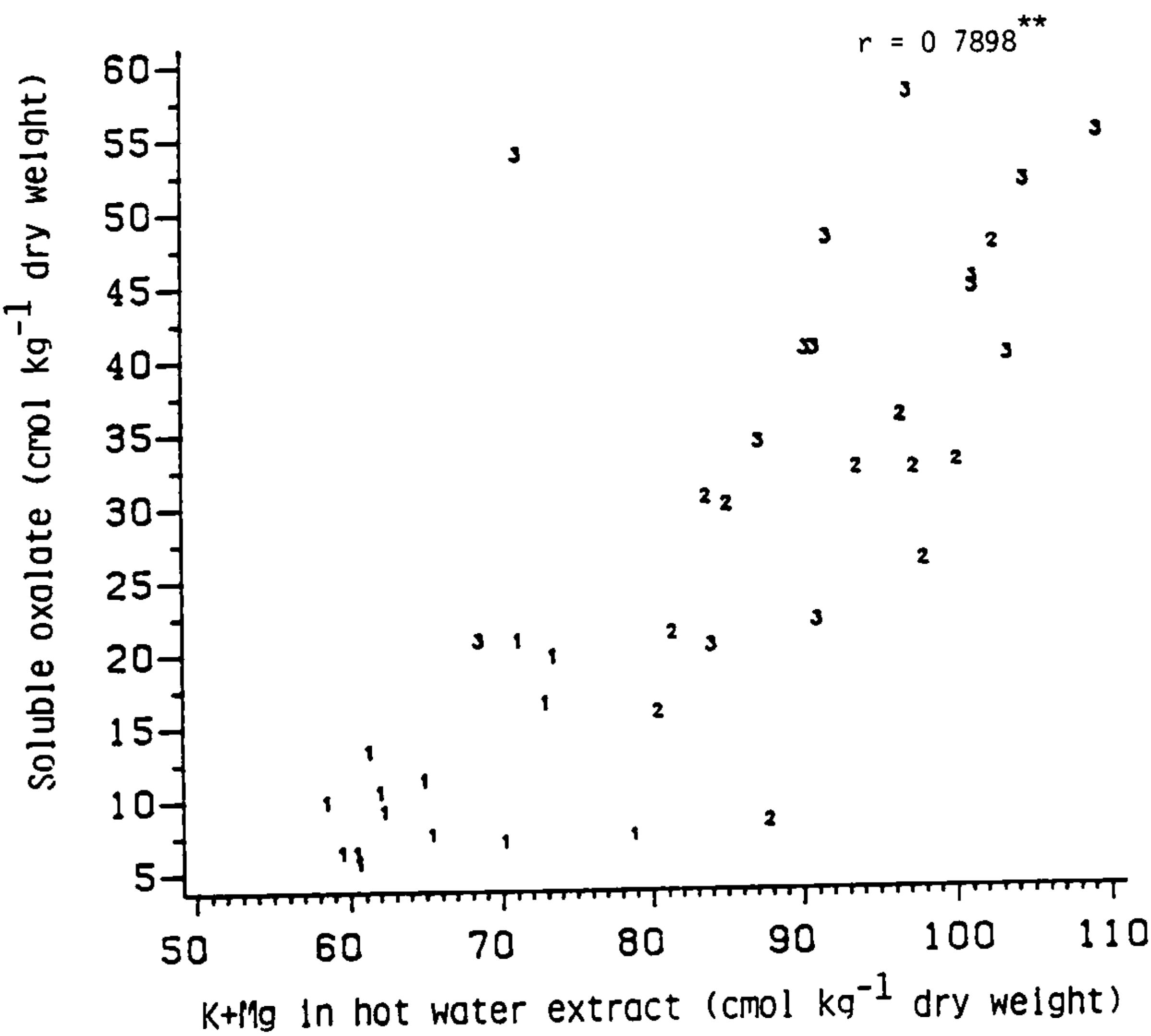


Figure 4 41 Relationship between soluble oxalate and the sum of potassium and magnesium concentration in the extract of soluble oxalate fraction (hot water extract) of leaf tissue of taro grown at three sites (1=Kukaiau, 2=Iole 3=Waipio)

The analysis of mineral concentrations, including Ca Mg, K and Na in the soluble and insoluble fraction also shows that the dominant cation in the soluble fraction was K while Ca appears to dominate in the insoluble fraction (Table 4 59) Little Ca was found in the soluble fraction and little K was found in the insoluble fraction

Ca oxalate crystals are known to be plentiful in taro leaves (Sunell and Arditti, 1983) These crystals have been implicated in the irritant quality of taro Sunell and Arditti (1983) suggested that Ca oxalate plays a role in Ca balance within the plant Sunell and Healey (1979) reported that Ca oxalate in taro was not metabolically inactive because crystal numbers and density changed during plant development The finding of soluble oxalate in taro implies that Ca from other foods can be bound and rendered unavailable

4 4 2 Comparison of chemical composition of plants grown at different sites

Significantly higher soluble oxalate was found in plants from the Tropeptic Eutrustox soil at the Waipio site than in plants grown in the Hydric Dystrandept soils at Kukaiau and Iole (Table 4 60) Furthermore for soils of the same family of Hydric Dystrandepts, plants from Iole had significantly higher soluble oxalate than plants from Kukaiau (Table 4 60) Plants grown at Waipio and Iole had significantly higher tissue K and Mg concentrations than did plants at Kukaiau (Table 4 61) Higher soluble oxalate was also found in Waipio and Iole plants Although Iole plants had almost equal concentrations of tissue K as the Waipio plants, they had significantly higher tissue Ca This was

Table 4 59

Mineral concentrations in the soluble and insoluble fraction of extracts of oxalate in taro grown at three sites

Site	cmol kg^{-1} dry weight									
	Soluble fraction					Insoluble fraction				
	Oxalate	Ca	Mg	K	Na	Oxalate	Ca	Mg	K	Na
Kukaiau	10 9	2 6	16 4	49 4	0 22	52 5	101 4	14 6	2 1	0 90
Iole	28 5	2 3	20 8	71 2	0 31	56 7	78 6	16 3	2 4	0 84
Waipio	41 1	1 5	27 3	65 0	0 25	42 4	62 3	16 7	2 3	0 62

Table 4 60

Oxalate concentrations of taro leaves grown at three different experimental sites

Site	cmol kg^{-1} dry weight		
	Soluble* oxalate	Insoluble* oxalate	Soluble + Insoluble* oxalate
Kukaiau	10 9 C	52 5 A[a]	63 4 B
Iole	28 5 B	56 7 A[b]	85 2 A
Waipio	41 1 A	42 4 A[c]	83 5 A

* Means in the same column followed by the same capital letter are not significantly different at 0 05 probability level (Waller-Duncan s multiple range test)

[a] 12 7 mg/g FW

[b] 13 7 mg/g FW

[c] 10 3 mg/g FW

probably the reason for the lower soluble oxalate in plants grown at Iole than at Waipio

Plants from the Hydric Dystrandept soils contained higher insoluble oxalate than plants grown in the Tropeptic Eutrustox soil This was associated with the significantly higher tissue Ca in plants from the Hydric Dystrandepts (Table 4 61)

Table 4 60 also shows that while the insoluble oxalate did not vary with site the soluble fraction did Tissue Ca was higher in plants from Kukaiau than from Iole and Waipio while tissue K was higher in Iole and Waipio than in plants from Kukaiau (Table 4 61) This probably led to the higher proportion of insoluble oxalate and a lower proportion

Table 4 61

Ionic concentrations and cation excess in taro leaves grown in three experimental sites

Site	cmol kg 1 dry weight (% dry weight)										
	Ca	Mg	K	Na	SC[a]	P	S	NO_3	Cl	SA[b]	C A
Kukaiau	131 7 A[c] (2 6)[d]	33 3 C[c] (0 4)	90 6 B[c] (3 5)	1 1 A[c] (0 03)	256 8 A[c]	3 2 C[c] (0 31)	5 9 A[c] (0 3)	7 1 A[c]	36 6 A[c] (1 3)	52 7 A[c]	204 1 A[c]
Iole	110 3 B (2 2)	43 7 B (0 5)	111 1 A (4 3)	1 1 A (0 03)	266 2 A	3 8 B (0 37)	5 6 A (0 3)	7 2 A	28 9 B (1 0)	45 5 B	220 7 A
Waipio	90 5 C (1 8)	54 2 A (0 7)	111 5 A (4 3)	0 9 B (0 02)	257 1 A	4 5 A (0 44)	5 6 A (0 3)	6 8 A	39 9 A (1 3)	51 8 A	205 3 A

[a]Sum of cations

[b]Sum of anions

[c]Means in the same column followed by same capital letter are not significantly different at 0 05 probability level (Waller Duncan s multiple range test)

[d]Ionic concentrations in the unit of % on a dry weight basis

of soluble oxalate in plants grown at Kukaiau (Table 4 62) On the other hand Waipio plants had lower tissue Ca and higher tissue K than Kukaiau plants (Table 4 61) which probably led to a higher proportion of soluble oxalate and a lower proportion of Ca oxalate than at Kukaiau (Table 4 62) Plant Mg and soluble oxalate contents at Iole were lower than in plants from Waipio while Ca and insoluble oxalate contents were higher

Table 4 62

Comparative concentrations of different forms of oxalate as percentage of soluble + insoluble oxalate in taro leaves from three sites

Site	% of soluble + insoluble oxalate	
	Soluble* oxalate	Insoluble* oxalate
Kukaiau	17 2 C	82 8 A
Iole	33 5 B	66 5 A
Waipio	49 2 A	50 8 A

* Means in the same column followed by the same letter are not significantly different at 0 05 probability level (Waller-Duncan s multiple range test)

de la Pena and Plucknett (1969) found that addition of K to upland and lowland taro reduced the concentration of Ca as well as Mg Simple correlation (Appendix F) of data from all sites shows that soil Ca was negatively correlated with tissue Ca while tissue Ca was, in turn negatively correlated with tissue K Tissue K and soil K however, were positively correlated indicating that K may be the most important soil variable influencing taro soluble oxalate content in Table 4 67

The high concentration of Cl (1 0-1 3%) in taro leaves (Table 4 61) is of interest It was more than 5 times higher than in leaves of amaranth and cassava (0 2-0 3% dry weight) According to Mengel and Kirkby (1978), Cl content of most plants generally range from 0 2-2 0% dry weight For Cl sensitive crops, the reduction in yields was associated with tissue levels of 0 5-2 0% Cl Spinach and beetroot are considered halophytes and contain Cl content ranging from 0 5-2 2% dry weight (Vityakon, 1979) These facts suggest that taro is of high Cl plant

<u>Oxalate and calcium concentration in taro leaves</u>

Approximately 40 to 50 percent of Ca was in the forms of Ca oxalate (Table 4 63) Therefore, about half of the total tissue Ca in taro leaves should not be available to humans The plant maintained a sizable soluble oxalate pool despite a large quantity of Ca unbound by oxalate The mechanism by which taro maintains a high soluble oxalate pool in the presence of high plant Ca concentration cannot be explained at this time

<u>Relationship between oxalate and cation excess</u>

Oxalate constituted from 30 to 40 percent of the cation excess in plants at the various sites (Table 4 64) Significant relationships between oxalates and cation excess were found in insoluble oxalate from combined data of three experimental sites and soluble and insoluble oxalate in Waipio site (Table 4 65) The sum of soluble and insoluble oxalate was not significantly correlated with cation excess In

Table 4 63

Calcium in the form of calcium oxalate in taro leaves grown at three sites

Site	cmol kg^{-1} dry weight		
	Insoluble oxalate	Tissue Ca	Ca oxalate (% tissue Ca)
Kukaiau	52 5	131 7	39 9
Iole	56 7	110 3	51 4
Waipio	42 4	90 5	46 9

Table 4 64

Total oxalate as percentage of cation excess in taro leaves from three experimental sites

Site	% cation excess
Kukaiau	31 1
Iole	38 6
Waipio	40 7

contrast to other plants, it appears that oxalates in taro were more closely related with specific cations (Table 4 58) than with cation excess

Total N nitrate-N and crude protein contents

Significantly higher total N was found in taro leaves from the Iole site than in leaves from Kukaiau and Waipio (Table 4 66) This is likely because Iole soil has higher N content The levels of nitrate-N in the leaves were below the dangerous level in all cases

At Iole site crude protein content of taro leaves was similar to that of amaranth and cassava while at Kukaiau the levels were lower (Tables 4 66, 4 52, and 4 18)

Table 4 65

Correlation between oxalates and cation excess in taro leaves

oxalate	correlation coefficient (Probability > |r|)			
	combined[a] 3 sites	Kukaiau[b]	Iole[b]	Waipio[b]
Soluble	ns*	ns	ns	-0 7170 (0 0039)
Insoluble	0 3854 (0 0154)	ns ns	ns ns	0 7747 (0 0011)
Soluble+ Insoluble	ns	ns	ns	ns

* ns = non-significant

[a]Number of observations = 42

[b]Number of observations = 14

Table 4 66

Total N, nitrate-N and crude protein concentrations of taro leaves grown at three sites

Site	% dry weight		
	Total N*	Nitrate-N*	Crude protein*
Kukaiau	3 9 B	0 10 A	24 4 B
Iole	4 6 A	0 10 A	28 8 A
Waipio	3 8 B	0 09 A	23 8 B

* Means in the same column followed by the same letter are not significantly different at 0 05 probability level (Waller-Duncan s multiple range test)

4 4 3 Relationships between oxalates in taro leaves and soil and climatic variables

Soluble oxalate in taro leaves was positively correlated with soil Ca, Mg, K, and Na and negatively correlated with soil P (Table 4 67) This is consistent with the cation-anion balance concept in which increasing cation content leads to an increase in cation excess and consequently to an increase in the synthesis of organic acid On the other hand, increasing anion concentration leads to a decrease in cation excess and a consequent decrease in organic acid content

Soluble oxalate was correlated with climatic variables while no correlation was observed for insoluble oxalate or the sum of soluble and insoluble oxalate (Table 4 68) Soluble oxalate in taro leaves was positively correlated with air and soil temperature as was the case with amaranth and cassava Both rainfall and relative humidity however, were negatively correlated with soluble oxalate A correlation matrix (Appendix F) shows that radiation, air temperature soil temperature, relative humidity, rainfall, and wind speed were all highly correlated Thus when radiation was high temperature was high, rainfall was more likely and the air was more turbulent It is likely that one variable serves as a surrogate for all others In any case the climate was sufficiently different among sites to have caused differences in the soluble oxalate content

Table 4 67

Correlation between taro oxalates and soil variables from three experimental sites

Element	Corrleation coefficient* (Probability >|r|)		
	Soluble oxalate	Insoluble oxalate	Soluble+insoluble oxalate
Soil Ca	0 7020 (0 0001)	ns**	0 4756 (0 0022)
Mg	0 7400 (0 0001)	ns	ns
K	0 7161 (0 0001)	ns	ns
Na	0 6747 (0 0001)	ns	ns
P	-0 7618 (0 0001)	ns	-0 4714 (0 0025)

* Number of observations = 42
** ns = non-significant

Table 4 68

Correlation between taro oxalates and climatic variables from three experimental sites

Climatic variables	Correlation coefficient* (Probablity > |r|)		
	Soluble oxalate	Insoluble oxalate	Soluble+Insoluble oxalate
Average air temperature	0 5168 (0 0008)	ns**	ns
Average relative humidity	-0 5626 (0 0002)	ns	ns
Average topsoil temperature	ns	ns	ns
Average subsoil temperature	0 7113 (0 0001)	ns	ns
Rainfall	-0 7219 (0 0001)	ns	ns
Radiation	0 6227 (0 0001)	ns	ns
Wind speed	-0 5412 (0 0004)	ns	ns

* Number of observations = 42
** ns = non-significant

CHAPTER V

SUMMARY AND CONCLUSIONS

This study provides new evidence to support the hypothesis that plant composition is strongly influenced by the same environmental factors that regulate plant growth and development While it is well known that soil fertility affects the mineral nutrition of plants, the effect of soil fertility on the antinutrient content of plants has heretofore not been well documented This study also shows that the effect of soil fertility on plant composition in general, and antinutrient in particular, is strongly modified by atmospheric conditions The situation is further complicated by the fact that plant utilization of soil phosphorus and bases is controlled first by soil nitrogen and only secondarily by the amount of phosphorus and bases present in the soil Furthermore, plant composition is determined to a larger extent by plant genotype than by environmental factors

Plant oxalate and cation excess is significantly related although in some cases better relationships are found between oxalate and individual cations The results of this study support earlier studies which show that oxalate is produced in response to cation excess In addition, the forms of oxalate produced depend on the dominant cations in the plant tissue

Tables 5 1 and 5 2 summarized the effects of soil and climatic factors and cation excess on the oxalate and nitrate contents of three crops Soil and climate affect cation excess (C-A) which in turn affect oxalate content

Table 5 1 summarizes the important relationships that exist between soil-climate factors and oxalate and nitrate contents The results show that these relationships differ for different crops Through multiple regression analysis (Table 5 2) the key factors influencing individual plant constituents are identified Formation of different forms of oxalate in the same plant is influenced by different environmental factors The fact that solar radiation air temperature and wind speed appear in the equations show that weather variables contribute measurably to plant composition

These findings suggest that nutritional quality of crops can be controlled through crop selection and management of the environment If as much attention is given to improving nutritional quality of food crops as is now given to increasing yields the goal of meeting the nutritional needs of people will be more readily served

Table 5 1

Soil climatic factors and cation excess correlated with the concentration of oxalates and nitrate N in amaranth cassava and taro

Positive and negative signs are those of the correlation coefficients Asterisks represent significance level where there is no asterisk the correlation is not significant

Crop	Plant composition	Cation excess (C A)	Soil					Climate					
								Av temperature					
			N	P	Ca	Mg	K	Air	Subsoil	Rainfall	Radiation	Wind speed	Relative humidity
AMARANTH	Soluble oxalate		+		*			+		+			
	Insol oxalate	+**	+							+**			+*
	Total oxalate	+ *	+ *		**	**	*			+**	**	**	+
	Sol + Insol oxalate	+ *	+*	*	**					+*	**		+
	NO_3 N		+**		**	**	**	*		+**	*	**	+
CASSAVA	Insol oxalate	+		+		+*	+	+	+*		+	+	*
	Total oxalate	+			+	+*	+*	+	+*	*	+		
	NO_3 N			*	+	+**	+**	+	+ *	-**	+**	+	
TARO	Soluble oxalate			**	+ *	+**	+**	+*	+**	**	+**	**	**
	Insol oxalate	+*		+						+		+	+
	Sol + insol oxalate	+			+	+		+	+		+		
	NO_3 N			+						+		+	+

Table 5 2

Variables identified through multiple regression analysis to contribute significantly to the oxalate and nitrate contents of amaranth

Plant composition (Y)[a]	X variables[b]	Contributions[c]	
Total oxalate (NI)	SRSQ	-	ns
	PLEVEL	-	*
	SOLMG	+	**
	SOLK	+	*
Total oxalate (I)	SRSQ	+	**
	NLEVEL	+	**
	SOLK	+	ns
	AIR4SQ	-	**
Soluble oxalate (NI)	SOLK	+	**
	PLEVEL	-	**
	SOLCA	-	**
	SOLP	+	ns
Soluble oxalate (I)	AIR2	+	**
	PLEVEL	-	**
Insoluble oxalate (NI)	SOLP	-	**
	PLEVEL	+	**
Insoluble oxalate (I)	AIR3	-	**
	NLEVEL	+	*
	PLEVEL	+	ns
Nitrate-N (NI)	WSPSQ	-	ns
	NLEVEL	+	**
	SOLMG	-	**
	SOLK	+	*
Nitrate-N (I)	AIR2SQ	+	**
	NLEVEL	+	**
	SOLTN	+	**

Table 5 2 (continued) Variables identified through multiple regression analysis to contribute significantly to the oxalate and nitrate contents of amaranth

Notes

[a]NI = non-irrigated plants
I = irrigated plants

[b]SRSQ	=	Square of solar radiation
PLEVEL	=	Fertilizer P rate
SOLMG	=	Soil magnesium content
SOLK	=	Soil potassium content
NLEVEL	=	Fertilizer N rate
AIR4SQ	=	Square of the difference between maximum and minimum temperature
SOLCA	=	Soil Calcium content
SOLP	=	Soil phosphorus content
AIR2	=	Minimum air temperture
AIR3	=	Average air temperature
WSPSQ	=	Square of wind speed
AIR2SQ	=	Square of minimum air temperature
SOLTN	=	Soil total nitrogen content

[c]Positive and negative signs are those of the parameter estimates or regression coefficients in the regression equations Asterisks indicate the significance level (Probability > /t/)

Appendix A Analysis of variance of various dependent variables using combined data of amaranth experiments from three sites

DEPENDENT VARIABLE DW

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	161983 94320755	5585 65321405	1 76	0 0829	0 689963	90 8982
ERROR	23	72788 15000000	3164 70217391		ROOT MSE		DW MEAN
CORRECTED TOTAL	52	234772 09320755			56 25568570		61 88867925

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC		53960 48863238	8 52	0 0017	2	46752 66914530	7 39	0 0033
REP(LOC)	6	28205 65624183	1 49	0 2272	6	28750 16394444	1 51	0 2179
IRR	1	4 90926030	0 00	0 9689	1	30 69160000	0 01	0 9224
LOC*IRR	2	7[illegible]44 04052128	1 14	0 3359	2	5937 61000000	0 94	0 4056
REP*IRR(LO)	6	33153 24519841	1 75	0 1553	6	31278 73727778	1 65	0 1765
FER	2	6017 66287582	0 95	0 4011	2	5605 98299145	0 89	0 4260
LOC FER	4	10307 14401307	0 83	0 5198	4	10201 19198413	0 81	0 5341
IRR FER	2	11415 57969841	1 80	0 1872	2	11715 56418803	1 85	0 1797
LOC IRR FER	4	11535 01674603	0 91	0 4740	4	11535 01674603	0 91	0 4740

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC		467[illegible]2 66914530	4 88	0 0552

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	30 69160000	0 01	0 9413
LOC IR		[illegible] 37 61000000	0 [illegible]7	0 [illegible]937

DEPENDENT VARIABLE DX

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	30674 42102030	1057 73865587	2 32	0 0230	0 753286	11 5023
ERROR	22	10046 39507778	456 65432172		ROOT MSE		DX MEAN
CORRECTED TOTAL	51	40720 81609808			21 36947172		185 78480769

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	13080 02383697	14 32	0 0001	2	13063 06080556	14 30	0 0001
REP(LOC)	6	2510 51038611	0 92	0 5019	6	2025 96052500	0 74	0 6236
IRR	1	143 89200441	0 32	0 5802	1	74 55628929	0 16	0 6901
LOC*IRR	2	720 58470503	0 79	0 4667	2	467 43162500	0 51	0 6064
REP*IRR(LOC)	6	1503 68849889	0 55	0 7656	6	1603 49258611	0 59	0 7384
FER	2	7415 00198824	8 12	0 0023	2	6985 42854444	7 65	0 0030
LOC*FER	4	618 96349621	0 34	0 8488	4	691 88775952	0 38	0 8213
IRR FER	2	2253 11882587	2 47	0 1080	2	2357 31250000	2 58	0 0984
LOC*IRR FER	4	2428 63727857	1 33	0 2903	4	2428 63727857	1 33	0 2903

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	13063 06080556	19 34	0 0024

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	74 55628929	0 28	0 6163
LOC IRR	2	467 43162500	0 87	0 4642

DEPENDENT VARIABLE: OX2

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	29545 43161765	1018 80798682	6 59	0 0001	0 885238	15 4143
ERROR	21	3830 27583333	182 39408730		ROOT MSE		OX2 MEAN
CORRECTED TOTAL	50	33375 70745098			13 50533551		87 61568627

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	7790 28033987	21 36	0 0001	2	7873 92118056	21 58	0 0001
REP(LOC)	6	3478 80744444	3 18	0 0222	6	3360 22598291	3 07	0 0256
IRR	1	103 28832129	0 57	0 4601	1	59 16035714	0 32	0 5750
LOC*IRR	2	987 52992026	2 71	0 0899	2	768 43340278	2 11	0 1466
REP*IRR(LOC)	6	847 28975845	0 77	0 5989	6	901 10940171	0 82	0 5645
FER	2	9739 90931373	26 70	0 0001	2	7194 00425214	19 72	0 0001
LOC*FER	4	4741 53954739	6 50	0 0014	4	4796 87286905	6 57	0 0014
IRR*FER	2	75 70569048	0 21	0 8142	2	69 83775641	0 19	0 8272
LOC*IRR*FER	4	1781 08128175	2 44	0 0786	4	1781 08128175	2 44	0 0786

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	7873 92118056	7 03	0 0268

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	59 16035714	0 39	0 5534
LOC*IRR	2	768 43340278	2 56	0 1572

DEPENDENT VARIABLE: OX3

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	15119 35227124	521 35697487	4 03	0 0008	0 847740	9 9340
ERROR	21	2715 53361111	129 31112434		ROOT MSE		OX3 MEAN
CORRECTED TOTAL	50	17834 88588235			11 37150493		114 47058824

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	4017 31466013	15 53	0 0001	2	3782 33027778	14 62	0 0001
REP(LOC)	6	1682 74172222	2 17	0 0876	6	859 90401709	1 11	0 3906
IRR	1	396 89855622	3 07	0 0944	1	569 70321429	4 41	0 0481
LOC*IRR	2	4519 61253798	17 48	0 0001	2	3534 00250000	13 66	0 0002
REP*IRR(LOC)	6	865 88007246	1 12	0 3865	6	885 74940718	1 14	0 3733
FER	2	1244 78235294	4 81	0 0190	2	1131 71008410	4 38	0 0258
LOC FER	4	1084 94628595	2 10	0 1172	4	1033 68604365	2 00	0 1317
IRR*FER	2	875 70054762	3 39	0 0531	2	810 54006410	3 13	0 0644
LOC*IRR*FER	4	431 47553571	0 83	0 5186	4	431 47553571	0 83	0 5186

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	3782 33027778	13 20	0 0064

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	569 70321429	3 86	0 0971
LOC IRR	2	3534 00250000	11 97	0 0080

DEPENDENT VARIABLE: OX2_3

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	26769 12160327	923 07315529	3 79	0 0012	0 839495	7 7251
ERROR	21	5118 03888889	243 71613757		ROOT MSE		OX2_3 MEAN
CORRECTED TOTAL	50	31887 16039216			15 61141049		202 08627451

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	4491 12916993	9 21	0 0013	2	4466 84090278	9 16	0 0014
REP(LOC)	6	7541 51672222	5 16	0 0021	6	5738 09350427	3 92	0 0087
IRR	1	905 13124699	3 71	0 0676	1	996 03571429	4 09	0 0561
LOC*IRR	2	1282 68545108	2 63	0 0956	2	1007 34923611	2 07	0 1516
REP*IRR(LOC)	6	1143 39780193	0 78	0 5935	6	1149 07401709	0 79	0 5908
FER	2	4452 20049020	9 13	0 0014	2	3080 68675214	6 32	0 0071
LOC*FER	4	4863 59406536	4 99	0 0055	4	4719 81592063	4 84	0 0063
IRR*FER	2	1212 84104762	2 49	0 1072	2	1041 69641026	2 14	0 1430
LOC*IRR*FER	4	876 72550794	0 90	0 4820	4	876 72550794	0 90	0 4820

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	4466 84090278	2 34	0 1776

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	996 03571429	5 20	0 0628
LOC IRR	2	1007 34923611	2 63	0 1513

DEPENDENT VARIABLE: TN

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	26 49339419	0 91356532	10 14	0 0001	0 930392	7 4624
ERROR	22	1 98212889	0 09009677		ROOT MSE		TN MEAN
CORRECTED TOTAL	51	28 47552308			0 30016124		4 02230769

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	15 68727933	87 06	0 0001	2	15 22261719	84 48	0 0001
REP(LOC)	6	1 42340708	2 63	0 0448	6	1 24943475	2 31	0 0699
IRR	1	0 37758519	4 19	0 0528	1	0 54522250	6 05	0 0222
LOC*IRR	2	2 98283335	16 55	0 0001	2	2 98079235	16.54	0 0001
REP*IRR(LOC)	6	0 98276812	1 82	0 1418	6	0 89547717	1 66	0 1791
FER	2	3 77162004	20 93	0 0001	2	3 36979891	18 70	0 0001
LOC*FER	4	0 57809056	1 60	0 2087	4	0 61015731	1 69	0 1875
IRR*FER	2	0 19644556	1 09	0 3536	2	0 20136184	1 12	0 3450
LOC*IRR*FER	4	0 49336495	1 37	0 2769	4	0 49336495	1 37	0 2769

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	15 22261719	36 55	0 0004

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 54522250	3 65	0 1045
LOC*IRR	2	2 98079235	9 99	0 0123

DEPENDENT VARIABLE CC_A

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	23827 73762294	821 64612493	2 69	0 0098	0 779950	5 4646
ERROR	22	6722 62040574	305 57365481		ROOT MSE		CC_A MEAN
CORRECTED TOTAL	51	30550 35802868			17 48066517		319 89121154

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	9578 85374351	15 67	0 0001	2	10073 49258838	16 48	0 0001
REP(LOC)	6	838 15596393	0 46	0 8322	6	774 86893659	0 42	0 8559
IRR	1	1733 29843932	5 67	0 0263	1	1858 55735195	6 08	0 0219
LOC*IRR	2	222 01862814	0 36	0 6995	2	248 45498341	0 41	0 6709
REP*IRR(LOC)	6	3642 07162111	1 99	0 1112	6	3802 57991659	2 07	0 0981
FER	2	1409 22027253	2 31	0 1233	2	957 80107189	1 57	0 2310
LOC FER	4	3527 39921805	2 89	0 0462	4	3572 29800966	2 92	0 0443
IRR*FER	2	994 68591746	1 63	0 2192	2	1185 21693417	1 94	0 1676
LOC*IRR*FER	4	1882 03381889	1 54	0 2255	4	1882 03381889	1 54	0 2255

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	10073 49258838	39 00	0 0004

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	1858 55735195	2 93	0 1376
LOC*IRR		748 4549P141	0 0	0 1 71

DEPENDENT VARIABLE CA

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	19533 06666667	673 55402299	4 50	0 0003	0 855681	10 1976
ERROR	22	3294 43333333	149 74696970		ROOT MSE		CA MEAN
CORRECTED TOTAL	51	22827 50000000			12 23711444		120 00000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	9709 27777778	32 42	0 0001	2	10222 69738562	34 13	0 0001
REP(LOC)	6	1416 43055556	1 58	0 2010	6	1707 17777778	1 90	0 1260
IRR	1	0 76918605	0 01	0 9435	1	8 63350694	0 06	0 8125
LOC*IRR	2	2565 47803618	8 57	0 0018	2	2586 30849673	8 64	0 0017
REP*IRR(LOC)	6	1304 25277778	1 45	0 2405	6	1537 91515152	1 71	0 1654
FER	2	1581 89859307	5 28	0 0134	2	1623 45657962	5 42	0 0122
LOC*FER	4	1536 09004329	2 56	0 0668	4	1630 81059028	2 72	0 0567
IRR*FER	2	382 59469697	1 28	0 2986	2	556 66395289	1 86	0 1796
LOC*IRR*FER	4	1036 27500000	1 73	0 1793	4	1036 27500000	1 73	0 1793

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	10222 69738562	17 96	0 0029

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	8 63350694	0 03	0 8604
LOC*IRR	2	2586 30849673	5 05	0 0519

DEPENDENT VARIABLE MG

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	9405 24194444	324 31868774	5 93	0 0001	0 886633	6 7381
ERROR	22	1202 57555556	54 66252525		ROOT MSE		MG MEAN
CORRECTED TOTAL	51	10607 81750000			7 39341093		109 72500000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	3279 80361111	30 00	0 0001	2	3249 08611111	29 72	0 0001
REP(LOC)	6	1293 66322222	3 94	0 0079	6	1236 19353535	3 77	0 0099
IRR	1	514 39779845	9 41	0 0056	1	446 66944444	8 17	0 0091
LOC*IRR	2	2028 21184258	18 55	0 0001	2	2022 59277778	18 50	0 0001
REP*IRR(LOC)	6	677 21102564	2 06	0 0994	6	607 68626263	1 65	0 1349
FER	2	428 88276190	3 92	0 0349	2	386 14247824	3 53	0 0467
LOC*FER	4	308 52400577	1 41	0 2632	4	281 69059028	1 29	0 3050
IRR*FER	2	29 44458649	0 27	0 7664	2	39 94057348	0 37	0 6981
LOC*IRR FER	4	845 10309028	3 87	0 0159	4	845 10309028	3 87	0 0159

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	3249 08611111	7 88	0 0209

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	446 66944444	4 41	0 0805
LOC*IRR	2	2022 59277778	9 99	0 0123

DEPENDENT VARIABLE K

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	19100 60673077	658 64161141	11 98	0 0001	0 940457	5 9394
ERROR	22	1209 32000000	54 96909091		ROOT MSE		K MEAN
CORRECTED TOTAL	51	20309 92673077			7 41411430		124 82884615

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	15072 96867521	137 10	0 0001	2	15249 02454248	138 71	0 0001
REP(LOC)	6	219 90172222	0 67	0 6772	6	250 06292929	0 76	0 6101
IRR	1	74 92931008	1 36	0 2555	1	114 18767361	2 08	0 1636
LOC*IRR	2	1540 36003180	14 01	0 0001	2	1447 08924837	13 16	0 0002
REP*IRR(LOC)	6	492 30865812	1 49	0 2267	6	444 01181818	1 35	0 2794
FER	2	360 28477489	3 28	0 0568	2	337 20438300	3 07	0 0668
LOC*FER	4	1044 27355844	4 75	0 0065	4	1068 91277778	4 86	0 0058
IRR*FER	2	27 49899306	0 25	0 7809	2	11 68776242	0 11	0 8996
LOC*IRR*FER	4	268 08100694	1 22	0 3311	4	268 08100694	1 22	0 3311

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	15249 02454248	182 94	0 0001

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	114 18767361	1 54	0 2605
LOC*IRR	2	1447 08924837	9 78	0 0129

DEPENDENT VARIABLE NA

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	429 85070085	14 82243796	46 15	0 0001	0 983827	9 1296
ERROR	22	7 06622222	0 32119192		ROOT MSE		NA MEAN
CORRECTED TOTAL	51	436 91692308			0 56673796		6 20769231

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	149 74477030	233 11	0 0001	2	151 06877778	235 17	0 0001
REP(LOC)	6	2 58715278	1 34	0 2809	6	2 20549495	1 14	0 3704
IRR	1	83 34760465	259 49	0 0001	1	71 69006250	223 20	0 0001
LOC*IRR	2	189 81336116	295 48	0 0001	2	189 70564052	295 32	0 0001
REP*IRR(LOC)	6	0 88570085	0 46	0 8304	6	0 92004040	0 48	0 8178
FER	2	1 35206494	2 10	0 1457	2	1 45575422	2 27	0 1274
LOC*FER	4	1 44879365	1 13	0 3691	4	1 48311806	1 15	0 3576
IRR*FER	2	0 31136364	0 48	0 6223	2	0 31639939	0 49	0 6177
LOC*IRR FER	4	0 35988889	0 28	0 8877	4	0 35988889	0 28	0 8877

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	151 06877778	205 49	0 0001

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	71 69006250	467 52	0 0001
LOC IRR	2	169 70564052	618 58	0 0001

DEPENDENT VARIABLE P

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	68 79967521	2 37240259	7 39	0 0001	0 906939	18 2959
ERROR	22	7 05955556	0 32088889		ROOT MSE		P MEAN
CORRECTED TOTAL	51	75 85923077			0 56647055		3 09615385

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	5 24374466	8 17	0 0022	2	5 62799346	8 77	0 0016
REP(LOC)	6	5 07315278	2 63	0 0444	6	5 02145455	2 61	0 0460
IRR	1	14 74140310	45 94	0 0001	1	12 41367361	38 69	0 0001
LOC*IRR	2	16 10981912	25 10	0 0001	2	16 66067320	25 96	0 0001
REP*IRR(LOC)	6	1 59277778	0 83	0 5613	6	1 38064646	0 72	0 6400
FER	2	16 47985734	25 68	0 0001	2	16 40856528	25 57	0 0001
LOC*FER	4	0 69564791	0 54	0 7066	4	0 54947222	0 43	0 7867
IRR*FER	2	2 87102273	4 47	0 0234	2	2 75697286	4 30	0 0266
LOC*IRR*FER	4	5 99225000	4 67	0 0070	4	5 99225000	4 67	0 0070

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	5 62799346	3 36	0 1048

TESTS OF HYPOT ESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	12 41367361	53 95	0 0003
LOC*IRR	2	16 66067320	36 20	0 0004

DEPENDENT VARIABLE S

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R SQUARE	C V
MODEL	29	83 19647863	2 86884409	4 09	0 0006	0 843633	9 0926
ERROR	22	15 42044444	0 70092929		ROOT MSE		S MEAN
CORRECTED TOTAL	51	98 61692308			0 83721520		9 20769231

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	27 65143697	19 72	0 0001	2	28 44043791	20 29	0 0001
REP(LOC)	6	8 81348611	2 10	0 0951	6	9 13591919	2 17	0 0852
IRR	1	0 10793798	0 15	0 6985	1	0 18000694	0 26	0 6174
LOC*IRR	2	6 27609620	4 48	0 0234	2	6 36279085	4 54	0 0224
REP IRR(LOC)	6	3 13796581	0 75	0 6188	6	2 67248485	0 64	0 7007
FER	2	11 49900433	8 20	0 0022	2	10 57339068	7 54	0 0032
LOC FER	4	14 97968254	5 34	0 0037	4	15 19139583	5 42	0 0034
IRR*FER	2	8 38030619	5 98	0 0084	2	8 20251510	5 85	0 0092
LOC*IRR*FER	4	2 35056250	0 84	0 5156	4	2 35056250	0 84	0 5156

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	28 44043791	9 34	0 0144

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 18000694	0 40	0 5484
LOC IRR	2	6 36279085	7 14	0 0259

DEPENDENT VARIABLE CNO3

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	10085 69494687	347 78258437	7 93	0 0001	0 912687	31 1067
ERROR	22	964 85602796	43 85709218		ROOT MSE		CNO3 MEAN
CORRECTED TOTAL	51	11050 55097483			6 62246874		21 28965769

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	4253 13023828	48 49	0 0001	2	4195 01888053	47 83	0 0001
REP(LOC)	6	434 94311532	1 65	0 1800	6	384 12788103	1 46	0 2377
IRR	1	594 60845560	13 56	0 0013	1	677 11915126	15 44	0 0007
LOC*IRR	2	529 18158622	6 03	0 0081	2	542 17082720	6 18	0 0074
REP*IRR(LOC)	6	293 08194678	1 11	0 3862	6	308 98509740	1 16	0 3611
FER	2	2387 03758561	27 21	0 0001	2	1955 11465509	22 29	0 0001
LOC*FER	4	871 94863629	4 97	0 0052	4	923 23447702	5 26	0 0040
IRR*FER	2	185 71796149	2 12	0 1442	2	219 87918835	2 51	0 1045
LOC*IRR*FER	4	536 04542132	3 06	0 0382	4	536 04542132	3 06	0 0382

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	4195 01888053	32 76	0 0006

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	677 11915126	13 28	0 0108
LOC*IRR	2	542 17082720	5 32	0 0470

DEPENDENT VARIABLE CL

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	40 72136752	1 40418509	9 37	0 0001	0 925130	5 3813
ERROR	22	3 29555556	0 14979798		ROOT MSE		CL MEAN
CORRECTED TOTAL	51	44 01692308			0 38703744		7 19230769

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	5 21692308	17 41	0 0001	2	5 19588235	17 34	0 0001
REP(LOC)	6	2 58700000	2 88	0 0317	6	2 41797980	2 69	0 0411
IRR	1	2 16931006	14 48	0 0010	1	1 95069444	13 02	0 0016
LOC*IRR	2	5 81883522	19 42	0 0001	2	5 84477124	19 51	0 0001
REP*IRR(LOC)	6	1 17318803	1 31	0 2960	6	0 78969697	0 88	0 5265
FER	2	15 48659307	51 69	0 0001	2	14 82580645	49 49	0 0001
LOC*FER	4	5 70739683	9 53	0 0001	4	5 77674479	9 64	0 0001
IRR*FER	2	1 17183475	3 91	0 0352	2	1 08763953	3 63	0 0434
LOC*IRR FER	4	1 39028646	2 32	0 0888	4	1 39028646	2 32	0 0888

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	5 19588235	6 45	0 0320

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	1 95069444	14 82	0 0085
LOC IRR	2	5 84477124	22 20	0 0017

DEPENDENT VARIABLE OXPRO

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	1370 32547083	47 25260244	1 68	0 1060	0 689230	98 3141
ERROR	22	617 87267008	28 08512137		ROOT MSE		OXPRO MEAN
CORRECTED TOTAL	51	1988 19814091			5 29953973		5 39041644

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	495 04570986	8 81	0 0015	2	463 44082323	8 25	0 0021
REP(LOC)	6	192 24677916	1 14	0 3722	6	136 04367554	0 81	0 5752
IRR	1	2 69880554	0 10	0 7595	1	11 35267560	0 40	0 5315
LOC*IRR	2	90 25966452	1 61	0 2232	2	103 57776817	1 84	0 1818
REP*IRR(LOC)	6	241 54006843	1 43	0 2468	6	186 25425348	1 11	0 3907
FER	2	20 87636827	0 37	0 6938	2	8 72135303	0 16	0 8571
LOC*FER	4	95 52468136	0 85	0 5067	4	125 80635907	1 12	0 3728
IRR FER	2	89 57848280	1 59	0 2255	2	112 41489910	2 00	0 1590
LOC*IRR FER	4	142 55491069	1 27	0 3121	4	142 55491069	1 27	0 3121

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	463 44082323	10 22	0 0117

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	11 35267560	0 37	0 5675
LOC*IRR	2	103 57776817	1 67	0 2654

DEPENDENT VARIABLE OX2PRO

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R SQUARE	C V
MODEL	29	180 92517959	6 23879930	4 64	0 0003	0 865086	52 6922
ERROR	21	28 21612910	1 34362520		ROOT MSE		OX2PRO MEAN
CORRECTED TOTAL	50	209 14130869			1 15914848		2 19984946

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	57 35090060	21 34	0 0001	2	47 29569053	17 60	0 0001
REP(LOC)	6	29 15937187	3 62	0 0127	6	41 01352634	5 09	0 0023
IRR	1	0 42917358	0 32	0 5779	1	0 33370103	0 25	0 6234
LOC*IRR	2	14 25890201	5 31	0 0136	2	9 24462086	3 44	0 0510
REP*IRR(LOC)	6	50 66247590	6 28	0 0007	6	50 02870139	6 21	0 0007
FER	2	7 44869945	2 77	0 0854	2	9 69550232	3 61	0 0450
LOC*FER	4	16 08731322	2 99	0 0422	4	17 46074491	3 25	0 0319
IRR*FER	2	0 09540934	0 04	0 9652	2	0 07720909	0 03	0 9717
LOC*IRR*FER	4	5 43293363	1 01	0 4242	4	5 43293363	1 01	0 4242

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	47 29569053	3 46	0 1002

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 33370103	0 04	0 8480
LOC*IRR	2	9 24462086	0 55	0 6013

DEPENDENT VARIABLE OX3PRO

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	909 69247103	31 36870590	10 52	0 0001	0 935590	48 5498
ERROR	21	62 62660261	2 98221917		ROOT MSE		OX3PRO MEAN
CORRECTED TOT L	50	972 31907364			1 72691030		3 55698701

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	270 96996075	45 43	0 0001	2	231 82493311	38 87	0 0001
REP(LOC)	6	155 22881006	8 68	0 0001	6	226 31773602	12 65	0 0001
IRR	1	12 77723075	4 28	0 0510	1	11 65479605	3 91	0 0613
LOC*IRR	2	124 76557587	20 92	0 0001	2	79 43877109	13 32	0 0002
REP*IRR(LOC)	6	204 14172731	11 41	0 0001	6	211 79528326	11 84	0 0001
FER	2	71 68032885	12 02	0 0003	2	78 32234465	13 13	0 0002
LOC*FER	4	55 79711093	4 68	0 0074	4	56 79080664	4 76	0 0068
IRR FER	2	3 52202707	0 59	0 5630	2	1 67691309	0 28	0 7577
LOC*IRR*FER	4	10 80969945	0 91	0 4783	4	10 80969945	0 91	0 4783

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	231 82493311	3 07	0 1205

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	11 65479605	0 33	0 5864
LOC*IRR	2	79 43877109	1 13	0 3846

DEPENDENT VARIABLE OX2_3PRO

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	1871 19986692	64 52413334	8 16	0 0001	0 918476	48 8574
ERROR	21	166 08891053	7 90899574		ROOT MSE		OX2_3PRO MEAN
CORRECTED TOTAL	50	2037 28877745			2 81229368		5 75613059

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	574 72583796	36 33	0 0001	2	485 73760991	30 71	0 0001
REP(LOC)	6	317 52566634	6 69	0 0005	6	457 79418759	9 65	0 0001
IRR	1	17 84671518	2 26	0 1479	1	15 93270179	2 01	0 1705
LOC*IRR	2	222 13973772	14 04	0 0001	2	141 85786538	8 97	0 0015
REP*IRR(LOC)	6	456 71654666	9 62	0 0001	6	465 10602651	9 80	0 0001
FER	2	123 79445234	7 63	0 0029	2	140 16759132	8 86	0 0016
LOC*FER	4	126 90285599	4 01	0 0143	4	131 78225917	4 17	0 0122
IRR*FER	2	4 82291971	0 30	0 7404	2	2 33236113	0 15	0 8638
LOC*IRR FER	4	26 72513500	0 84	0 5125	4	26 72513500	0 84	0 5125

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	485 73760991	3 18	0 1142

TESTS OF YPOTHESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	15 93270179	0 21	0 6662
LOC IRR	2	141 85786538	0 92	0 4500

DEPENDENT V RI ELE INUPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R SQUARE	C V
MODEL	29	315 40643057	10 8760838	2 13	0 0356	0 737487	87 4313
ERROR	2	112 7106226	5 1032 010		ROOT MSE		INUPT MEAN
CORRECTED TOTAL	51	427 67749 23			2 2*503300		2 5837811

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	124 03925785	1 15	0 0003	2	118 22979106	11 8	0 0004
REP(LOC)	6	35 02411 46	1 14	0 707	6	41 43848854	1 5	0 2766
IRR	1	0 01779 25	0 00	0 9034	1	0 01349362	0 00	0 959
LOC*IRR	2	11 87712 57	1 16	0 8	2	1 063 1985	1 18	0 32 4
REP IRR(LO)	6	60 04253057	1 96	0 11*4	6	59 66977697	1 95	0 1174
FER	2	6 0 2888 0	0 9	0 812	2	59608824	0 5	0 6 6
LOC FER	4	19 834824 3	0 97	0 4429	4	26 60615528	1 0	0 2995
IRR*FER	2	21 46275307	2 10	0 1460	2	25 26720711	48	0 1072
LOC IR FE	4	37 0 516 77	1 82	0 1615	4	37 0*516577	1 82	0 1619

TE TS OF YP T ESES U ING T TYPE III M FOR REP(LOC) A N ERROR TERM

SOURCE	DF	TYPE III S	F V LUE	PR > F
LOC	2	11 22979106	8 56	0 0175

TE TS O I INC T I E III MS FOR EP IRR(LOC) S AN ERROR TER

SOURCE	D	T E III SS	F VALUE	PR > F
IRR	1	0 01349 62	0 00	0 9718
LOC I		12 06351985	0 61	0 57 (

DEPENDENT VARIABLE CAUPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	185 98212530	6 41317673	1 73	0 0950	0 694834	109 7495
ERROR	22	81 68204721	3 71282033		ROOT MSE		CAUPT MEAN
CORRECTED TOTAL	51	267 66417251			1 92686801		1 75569635

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	70 26926874	9 46	0 0011	2	69 90583438	9 41	0 0011
REP(LOC)	6	22 98775276	1 03	0 4314	6	34 92968774	1 57	0 2035
IRR	1	2 31814802	0 62	0 4379	1	3 02940802	0 82	0 3762
LOC*IRR	2	22 16023306	2 98	0 0713	2	20 64675113	2 78	0 0838
REP*IRR(LOC)	6	25 81194755	1 16	0 3632	6	35 15717545	1 58	0 2005
FER	2	10 72578076	1 44	0 2574	2	12 13515887	1 63	0 2179
LOC*FER	4	13 38812130	0 90	0 4800	4	17 35666077	1 17	0 3516
IRR*FER	2	7 49651270	1 01	0 3807	2	9 22302977	1 24	0 3083
LOC*IRR FER	4	10 82436041	0 73	0 5818	4	10 82436041	0 73	0 5818

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	69 90583438	6 00	0 0370

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	3 02940802	0 52	0 4992
LOC IRR	2	20 64675113	1 76	0 2501

DEPENDENT VARIABLE MGUPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R SQUARE	C V
MODEL	29	31 04856861	1 07064030	2 04	0 0441	0 729125	88 8196
ERROR	22	11 53473093	0 52430595		ROOT MSE		MGUPT MEAN
CORRECTED TOTAL	51	42 58329954			0 72408974		0 81523640

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	11 86727258	11 32	0 0004	2	11 34243347	10 82	0 0005
REP(LOC)	6	4 21511614	1 34	0 2819	6	5 03864243	1 60	0 1938
IRR	1	0 03298416	0 06	0 8043	1	0 07002644	0 13	0 7183
LOC IRR	2	1 68874690	1 61	0 2225	2	1 68110974	1 60	0 2239
REP*IRR( )	6	5 45586984	1 73	0 1601	6	5 60090764	1 78	0 1498
FER	2	0 58438550	0 56	0 5806	2	0 68490117	0 65	0 5302
LOC FER	4	2 16117296	1 03	0 4137	4	2 88757614	1 38	0 2743
IRR*FER	2	2 18158415	2 08	0 1488	2	2 51249361	2 40	0 1144
LOC IR FER	4	2 86143639	1 36	0 2784	4	2 86143639	1 36	0 2784

TESTS OF H POT ESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	11 342 33 7	6 75	0 0291

TESTS [illegible] USING THE TYPE III MS FOR REP IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 07002644	0 08	0 7934
[illegible]	2	1 68110974	0 90	0 4[illegible]0

DEPENDENT VARIABLE KUPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	353 05775377	12 17440530	2 18	0 0316	0 741974	79 1118
ERROR	22	122 77807647	5 58082166		ROOT MSE		KUPT MEAN
CORRECTED TOTAL	51	475 83583024			2 36237627		2 98612344

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	115 94632105	10 39	0 0007	2	109 26545098	9 79	0 0009
REP(LOC)	6	49 75309009	1 49	0 2290	6	60 15893377	1 80	0 1463
IRR	1	0 55438091	0 10	0 7556	1	0 23646382	0 04	0 8388
LOC*IRR	2	12 32299225	1 10	0 3492	2	12 62330391	1 13	0 3408
REP*IRR(LOC)	6	52 00248565	1 55	0 2079	6	55 45660507	1 66	0 1792
FER	2	17 14281351	1 54	0 2375	2	17 11774459	1 53	0 2379
LOC*FER	4	37 03789846	1 66	0 1953	4	46 11437821	2 07	0 1200
IRR*FER	2	27 71340066	2 48	0 1066	2	32 09720129	2 88	0 0777
LOC*IRR*FER	4	40 58437120	1 82	0 1613	4	40 58437120	1 82	0 1613

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	109 26545098	5 45	0 0448

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 23646382	0 03	0 8782
LOC IRR	2	12 62330391	0 68	0 5405

DEPENDENT VARIABLE NAUPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R SQUARE	C V
MODEL	29	0 19097197	0 00658524	2 15	0 0342	0 738975	70 9967
ERROR	22	0 06745628	0 00306619		ROOT MSE		NAUPT MEAN
CORRECTED TOTAL	51	0 25842825			0 05537323		0 07799413

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	0 04130449	6 74	0 0052	2	0 03725716	6 08	0 0079
REP(LOC)	6	0 02462949	1 34	0 2824	6	0 02902256	1 58	0 2007
IRR	1	0 00196054	0 64	0 4325	1	0 00203752	0 66	0 4237
LOC*IRR	2	0 01599707	2 61	0 0962	2	0 01599818	2 61	0 0962
REP*IRR(LOC)	6	0 03206937	1 74	0 1580	6	0 03504773	1 91	0 1251
FER	2	0 01001266	1 63	0 2182	2	0 00911378	1 49	0 2481
LOC*FER	4	0 02414091	1 97	0 1347	4	0 02820372	2 30	0 0910
IRR*FER	2	0 01675389	2 73	0 0871	2	0 01839146	3 00	0 0705
LOC*IRR*FER	4	0 02410355	1 97	0 1352	4	0 02410355	1 97	0 1352

TESTS OF YPOT ESES USI G THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	0 03725716	3 85	0 0840

TESTS OF OT ES S USING THE T PE III MS FOR REP IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F V LUE	PR > F
IRR	1	0 00203752	0 35	0 5763
LOC IRR	2	0 01599818	1 37	0 3237

DEPENDENT VARIABLE PUPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	1 29375298	0 04461217	3 43	0 0020	0 818795	65 8827
ERROR	22	0 28631707	0 01301441		ROOT MSE		PUPT MEAN
CORRECTED TOTAL	51	1 58007004			0 11408073		0 17315732

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	0 28721778	11 03	0 0005	2	0 25816426	9 92	0 0009
REP(LOC)	6	0 07107396	0 91	0 5058	6	0 12479149	1 60	0 1948
IRR	1	0 00000329	0 00	0 9875	1	0 00002691	0 00	0 9641
LOC*IRR	2	0 04021994	1 55	0 2355	2	0 04000701	1 54	0 2372
REP*IRR(LOC)	6	0 13795387	1 77	0 1528	6	0 18405811	2 36	0 0655
FER	2	0 25352938	9 74	0 0009	2	0 24634361	9 46	0 0011
LOC*FER	4	0 15025313	2 89	0 0462	4	0 17999021	3 46	0 0245
IRR*FER	2	0 10722778	4 12	0 0302	2	0 13188931	5 07	0 0155
LOC*IRR*FER	4	0 24627385	4 73	0 0066	4	0 24627385	4 73	0 0066

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	0 25816426	6 21	0 0346

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 00002691	0 00	0 9773
LOC IRR	2	0 04000701	0 65	0 5543

DEPENDENT VARIABLE SUPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R SQUARE	C V
MODEL	29	4 28822994	0 14787000	2 46	0 0165	0 764230	85 1767
ERROR	22	1 32294690	0 06013395		ROOT MSE		SUPT MEAN
CORRECTED TOTAL	51	5 61117684			0 24522225		0 28789818

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	1 41148009	11 74	0 0003	2	1 34027178	11 14	0 0005
REP(LOC)	6	0 60779052	1 68	0 1720	6	0 63492411	1 76	0 1543
IRR	1	0 00000001	0 00	0 9997	1	0 00112168	0 02	0 8926
LOC*IRR	2	0 19830616	1 65	0 2152	2	0 20263484	1 68	0 2085
REP IRR(LOC)	6	0 66449631	1 84	0 1371	6	0 65254234	1 81	0 1438
FER	2	0 20071887	1 67	0 2114	2	0 18286510	1 52	0 2407
LOC*FER	4	0 35340750	1 47	0 2454	4	0 42819208	1 78	0 1688
IRR*FER	2	0 42820744	3 56	0 0458	2	0 47404897	3 94	0 0344
LOC*IRR FER	4	0 42382304	1 76	0 1726	4	0 42382304	1 76	0 1726

TESTS OF H Y)T ESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	1 34027178	6 33	0 0332

TESTS T T E I S ING T E T I E III MS FOR REP IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 00112168	0 01	0 9224
LOC*IRR	2	0 20263484	0 91	0 443

DEPENDENT VARIABLE CNO3UPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	28 95884869	0 99858099	1 58	0 1362	0 675565	94 8423
ERROR	22	13 90729935	0 63214997		ROOT MSE		CNO3UPT MEAN
CORRECTED TOTAL	51	42 86614804			0 79507859		0 83831624

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	13 79743870	10 91	0 0005	2	12 75627104	10 09	0 0008
REP(LOC)	6	1 62888353	0 43	0 8513	6	3 04566020	0 80	0 5782
IRR	1	0 90032618	1 42	0 2454	1	0 93470430	1 48	0 2369
LOC*IRR	2	0 87192728	0 69	0 5123	2	0 84962251	0 67	0 5209
REP IRR(LOC)	6	6 30563118	1 66	0 1776	6	6 56682963	1 73	0 1608
FER	2	0 64234599	0 51	0 6085	2	0 17400975	0 14	0 8722
LOC*FER	4	1 48590837	0 59	0 6750	4	2 12793247	0 84	0 5137
IRR*FER	2	0 90916610	0 72	0 4983	2	1 34615841	1 06	0 3619
LOC*IRR*FER	4	2 41722137	0 96	0 4510	4	2 41722137	0 96	0 4510

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	12 75627104	12 57	0 0072

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP*IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 93470430	0 85	0 3911
LOC*IRR	2	0 84962251	0 39	0 6942

DEPENDENT VARIABLE CLUPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	29	1 18941065	0 04101416	2 30	0 0237	0 752275	83 1651
ERROR	22	0 39167453	0 01780339		ROOT MSE		CLUPT MEAN
CORRECTED TOTAL	51	1 58108518			0 13342934		0 16043911

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
LOC	2	0 32355786	9 09	0 0013	2	0 30637478	8 60	0 0017
REP(LOC)	6	0 18247664	1 71	0 1662	6	0 19803797	1 85	0 1347
IRR	1	0 00009060	0 01	0 9438	1	0 00070072	0 04	0 8446
LOC*IRR	2	0 05861622	1 65	0 2157	2	0 05941075	1 67	0 2115
REP*IRR(LOC)	6	0 18049761	1 69	0 1707	6	0 18790189	1 76	0 1545
FER	2	0 07958004	2 23	0 1307	2	0 07661700	2 15	0 1401
LOC*FER	4	0 12664877	1 78	0 1692	4	0 15367938	2 16	0 1075
IRR FER	2	0 11169402	3 14	0 0633	2	0 12589510	3 54	0 0466
LOC*IRR*FER	4	0 12624889	1 77	0 1703	4	0 12624889	1 77	0 1703

TESTS OF HYPOT ESES USING THE TYPE III MS FOR REP(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOC	2	0 30637478	4 64	0 0005

TESTS OF H OT ESES SI G THE T PE III MS FOR REP IRR(LOC) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 00070072	0 02	0 8860
LOC IRR	2	0 05941075	0 95	0 4360

Appendix B Analysis of variance of some dependent variables using data of amaranth experiment from Waipio site

DEPENDENT VARIABLE OX

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	9	7704 87791111	856 09754568	5 24	0 0145	0 854960	7 6881
ERROR	8	1307 10088889	163 38761111		ROOT MSE		OX MEAN
CORRECTED TOTAL	17	9011 97880000			12 78231634		166 26000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
IRR	1	130 68055556	0 80	0 3973	1	130 68055556	0 80	0 3973
REP(IRR)	4	831 39991111	1 27	0 3566	4	831 39991111	1 27	0 3566
FER	2	3834 65343333	11 73	0 0042	2	3834 65343333	11 73	0 0042
IRR*FER	2	2908 14401111	8 90	0 0092	2	2908 14401111	8 90	0 0092

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(IRR) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
		68055556	0 63	0 4722

DEPENDENT VARIABLE TN

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C V
MODEL	9	1 97024444	0 21891605	7 68	0 00 3	0 696299	5 1464
ERROR	8	0 2279 556	0 02849444		ROOT MSE		TN MEAN
CORRECTED TOTAL	17	2 19820000			0 16880298		3 28000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 28375556	9 96	0 0135	1	0 28375556	9 96	0 0135
REP(IRR)	4	0 95224444	8 35	0 0059	4	0 95224444	8 35	0 0059
FER	2	0 66223333	11 62	0 00 3	2	0 66223333	11 62	0 0043
IRR FER	2	0 07201111	1 26	0 333	2	0 07201111	1 26	0 3335

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(IRR) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IR	1	0 2 37 5	1 1	0 3363

DEPENDENT VARIABLE: DW

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	9	1887.82666667	209.75851852	5.02	0.0165	0.849641	21.3432
ERROR	8	334.08444444	41.76055556		ROOT MSE		DW MEAN
CORRECTED TOTAL	17	2221.91111111			6.4[illegible]24075		30.27777778

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
IRR	1	9.97555556	0.24	0.6381	1	9.97555556	0.24	0.6381
REP(IRR)	4	640.18888889	3.83	0.0502	4	640.188888[illegible]	3.83	0.0502
FER	2	302.22111111	3.62	0.0760	2	302.22111111	3.6[illegible]	0.0760
IRR*FER	2	935.44111111	11.20	0.0048	2	935.44111111	11.20	0.0048

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(IRR) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	9.97555556	[illegible].06	0.[illegible]

DEPENDENT VARIABLE: INUPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	9	2.43737688	0.27081965	6.09	0.0091	0.872565	21.2959
ERROR	8	0.35589310	0.04448664		ROOT MSE		INUPT MEAN
CORRECTED TOTAL	17	2.79326997			0.21091856		0.99041667

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0.00396347	0.09	0.7729	1	0.00396347	0.09	0.7729
REP(IRR)	4	0.43330019	2.44	0.1322	4	0.43330019	2.44	0.1322
FER	2	0.70529543	7.93	0.0127	2	0.70529543	7.9[illegible]	0.0127
IRR*FER	2	1.29481778	14.55	0.0022	2	1.29481778	14.[illegible]	0.0022

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(IRR) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0.00396347	0.04	0.8576

DEPENDENT VARIABLE: OXPRO

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	9	15.60238747	1.73359861	5.65	0.0115	0.8640	24.0145
ERROR	8	2.45478209	0.30684776		ROOT MSE		OXPRO MEAN
CORRECTED TOTAL	17	18.05716955			0.55393841		2.30668515

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0.06224345	0.20	0.6644	1	0.06224345	[illegible].[illegible]0	0.6644
REP(IRR)	4	2.51648640	2.05	0.1798	4	2.51648640	[illegible]	0.1798
FER	2	3.33236742	5.43	0.0324	2	3.33236742	[illegible]43	0.0324
IRR*FER	2	9.691290[illegible]0	15.79	0.0017	2	9.69129020	1[illegible].7[illegible]	0.0017

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(IRR) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0.062[illegible]4345	0.10	0.7[illegible]88

DEPENDENT VARIABLE CX2PRO

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R SQUARE	C V
MODEL	9	4 36409082	0 48489898	4 79	0 0190	0 843435	28 8P3
ERROR	8	0 80982497	0 10122812		ROOT MSE		CX2PRO MEAN
CORRECTED TOTAL	17	5 17391579			0 31816367		1 11291475

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 0069 600	0 07	0 8003	1	0 00692600	0 07	0 8003
REP(IRR)	4	0 48485509	1 20	0 3824	4	0 48485509	1 20	0 3824
FER	2	1 93274965	9 55	0 0076	2	1 93274965	9 55	0 0076
IRR FER	2	1 93956007	9 58	0 0075	2	1 93956007	9 58	0 0075

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(IRR) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 00692600	0 06	0 8228

DEPENDENT VARIABLE CX3PRO

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R SQUARE	C V
MODEL	9	5 50206222	0 61134025	4 66	0 0205	0 839944	23 9774
ERROR	8	1 04843425	0 13105428		ROOT MSE		CX3PRO MEAN
CORRECTED TOTAL	17	6 55049646			0 36201420		1 50981650

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 01562576	0 12	0 7388	1	0 01562 76	0 1	0 7388
REP(IRR)	4	1 34975279	2 57	0 1188	4	1 34975279	7	0 1188
FER	2	1 16762775	4 45	0 0501	2	1 16762775	4 45	0 0501
IRR FER	2	2 96905592	11 33	0 0046	2	2 96905 92	11	0 0046

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(IRR) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 01562576	0 05	0 8401

DEPENDENT VARIABLE CX2_3PRO

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R SQUARE	C V
MODEL	9	18 90977982	2 10108665	5 23	0 0146	0 8546	24 1771
ERROR	8	3 21667599	0 40208450		ROOT MSE		CX2_3PRO MEAN
CORRECTED TOTAL	17	22 12645581			0 63410133		2 62273125

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 00174561	0 00	0 9491	1	0 00174 61	0 00	0 9491
REP(IRR)	4	3 23770640	2 01	0 1055	4	3 23770640	01	0 1055
FER	2	5 98306294	7 44	0 0149	2	5 98306294	7 44	0 0149
IRR FER	2	9 68726487	12 05	0 0039	2	0 AR A		

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(IRR) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 00174561	0 00	0 9652

DEPENDENT VARIABLE CAUPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R SQUARE	C V
MODEL	9	0 85215347	0 09468372	4 45	0 0236	0 833394	23 2040
ERROR	8	0 17035629	0 02129454		ROOT MSE		CAUPT MEAN
CORRECTED TOTAL	17	1 02250975			0 14592647		0 62888444

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 04905756	2 30	0 1675	1	0 04905756	0	0 1675
REP(IRR)	4	0 26793979	3 15	0 0786	4	0 26793979	15	0 0786
FER	2	0 10468341	2 46	0 1472	2	0 10468341	46	0 1472
IRR*FER	2	0 43047272	10 11	0 0065	2	0 43047272	10 11	0 0065

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(IRR) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 04905756	0 73	0 4404

DEPENDENT VARIABLE MGUPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R SQUARE	C V
MODEL	9	0 37010666	0 04112296	4 72	0 0198	0 8414 1	23 1473
ERROR	8	0 06973652	0 00871707		ROOT MSE		MGUPT ME N
CORRECTED TOTAL	17	0 43984318			0 09336 23		0 40335267

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 01297841	1 49	0 2571	1	0 01297841	1 49	0 2571
REP(IRR)	4	0 08778966	2 52	0 1240	4	0 08778966	2 52	0 1240
FER	2	0 05571107	3 20	0 0955	2	0 05571107	20	0 09 5
IRR FER	2	0 21362752	12 25	0 0037	2	0 21362752	12 25	0 0037

TEST OF HYPOT ESES USING THE TYPE III MS FOR REP(IRR) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 01297841	0 59	0 4848

DEPENDENT VARIABL KUPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R SQUARE	C V
MODEL	9	4 47957869	0 49773097	7 37	0 0049	0 89234	20 1070
ERR	8	0 54044568	0 06755571		ROOT MSE		KUPT MEAN
CORRECTED TOT L	17	5 02002437			0 25991481		1 2926 955

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 000 4795	0 01	0 9305	1	0 00054795	0 01	0 9305
REP(IRR)	4	1 18383632	4 38	0 0362	4	1 18383632	4 38	0 0362
FER	2	1 2289 705	9 10	0 0097	2	1 22892705	9 10	0 0087
IRR FER	2	2 06626737	15 29	0 0018	2	2 06626737	15 9	0 0018

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(IRR) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 00054795	0 00	0 9677

DEPENDENT VARIABLE NAUPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R SQUARE	C V
MODEL	9	0 02433816	0 00270424	8 24	0 0034	0 902616	30 9688
ERROR	8	0 00262527	0 00032816		ROOT MSE		NAUPT MEAN
CORRECTED TOTAL	17	0 02696341			0 01811514		0 05849488

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 01176731	35 86	0 0003	1	0 01176731	3[illegible] 86	0 0003
REP(IRR)	4	0 00396216	3 02	0 0859	4	0 00396216	[illegible] 02	0 0859
FER	2	0 00350351	5 34	0 0337	2	0 00350351	[illegible] 34	0 0337
IRR FER	2	0 00510516	7 78	0 0133	2	0 00510516	7 78	0 0133

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(IRR) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 01176731	11 88	0 0261

DEPENDENT VARIABLE CATUPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R SQUARE	C V
MODEL	9	13 65301415	1 51700157	5 92	0 0099	0 869504	21 2342
ERROR	8	2 04905834	0 25613229		ROOT MSE		CATUPT MEAN
CORRECTED TOTAL	17	15 70207249			0 50609514		2 38339154

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 00059142	0 00	0 9629	1	0 00059142	0 00	0 9629
REP(IRR)	4	3 79943764	3 71	0 0542	4	3 79943764	3 71	0 0542
FER	2	2 95894433	5 78	0 0280	2	2 95894433	[illegible] 78	0 0280
IRR FER	2	6 89404076	13 46	0 0028	2	6 89404076	1[illegible] 46	0 0028

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(IRR) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 00059142	0 00	0 9813

DEPENDENT VARIABLE: PUPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	9	0.03555146	0.00395016	8.41	0.0032	0.904418	24.6119
ERROR	8	0.00375722	0.00046965		ROOT MSE		PUPT MEAN
CORRECTED TOTAL	17	0.03930868			0.02167146		0.08805281

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0.01758013	37.43	0.0003	1	0.01758013	7.43	0.0003
REP(IRR)	4	0.00840367	4.47	0.0343	4	0.00840367	4.47	0.034
FER	2	0.00458399	4.88	0.0412	2	0.00458399	4.88	0.0412
IRR*FER	2	0.00498367	5.31	0.0341	2	0.00498367	31	0.0341

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(IRR) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0.01758013	8.37	0.0444

DEPENDENT VARIABLE: SUPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	9	0.04147030	0.00460781	4.24	0.0270	0.82675	24.2335
ERROR	8	0.00868763	0.00108595		ROOT MSE		SUPT MEAN
CORRECTED TOTAL	17	0.05015793			0.03295301		0.135984 3

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0.00010905	0.10	0.7594	1	0.00010905	0.10	0.7594
REP(IRR)	4	0.01557094	3.58	0.0587	4	0.01557094	3.58	0.0 87
FER	2	0.00532060	2.45	0.1479	2	0.00532060	4	0.1479
IRR*FER	2	0.02046971	9.42	0.0079	2	0.02046971	5.42	0.0079

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(IRR) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0.00010905	0.03	0.8752

DEPENDENT VARIABLE: CNO3UPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	9	0.17787183	0.01976354	1.87	0.1956	0.67760	55.6447
ERROR	8	0.08462983	0.01057873		ROOT MSE		CNO3UPT MEAN
CORRECTED TOTAL	17	0.26250166			0.10285294		0.18483855

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0.00000510	0.00	0.9830	1	0.00000 10	0.00	0.9830
REP(IRR)	4	0.01668548	0.39	0.8076	4	0.01668548	0.39	0.8076
FER	2	0.07823272	3.70	0.0729	2	0.07823272	70	0.0729
IRR*FER	2	0.08294853	3.92	0.0650	2	0.08294853	3.92	0.0650

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(IRR) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0.00000510	0.00	0.9738

DEPENDENT VARIABLE CLUPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R SQUARE	C V
MODEL	9	0 01379198	0 00153244	4 01	0 0316	0 81866	24 0615
ERROR	8	0 00305500	0 00038187		ROOT MSE		CLUPT MEAN
CORRECTED TOTAL	17	0 01684698			0 01954161		0 08121512

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 000 7824	0 99	0 3488	1	0 00037824	0 99	0 3488
REP(IRR)	4	0 00632485	4 14	0 0416	4	0 00632485	4 14	0 0416
FER	2	0 00177535	2 32	0 1600	2	0 00177 5		0 1600
IRR FER	2	0 00531354	6 96	0 0178	2	0 00531354	6 96	0 0178

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(IRR) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 00037824	0 24	0 6504

DEPENDENT VARIABLE CANUPT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R SQUARE	C V
MODEL	9	0 59527955	0 06614217	2 83	0 0730	0 760856	31 2010
ERROR	8	0 18706022	0 02338253		ROOT MSE		CANUPT MEAN
CORRECTED TOTAL	17	0 78233977			0 15291346		0 49009104

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 02567099	1 10	0 3254	1	0 02567099	1 10	0 3254
REP(IRR)	4	0 06109292	0 65	0 6408	4	0 06109292	0 65	0 6408
FER	2	0 19208678	4 11	0 0593	2	0 19208679	4 11	0 0593
IRR FER	2	0 31642886	6 77	0 0191	2	0 31642886	6 77	0 0191

TESTS OF HYPOTHESES USING THE TYPE III MS FOR REP(IRR) AS AN ERROR TERM

SOURCE	DF	TYPE III SS	F VALUE	PR > F
IRR	1	0 02567099	1 68	0 2646

Appendix C Correlation matrix of oxalates and nitrate-N concentrations and various soil and climatic variables using data from non-irrigated plots of amaranth experiments at three sites

	OX	OX2	OX3	O23	NO3N	AIR1	AIR2	AIR3	AIR4	SOL1	SOL2	SOL3	SOL4
OX	1.00000 0.0000	0.67794 0.0001	0.19297 0.3149	0.63734 0.0004	0.61909 0.0006	0.30979 0.1159	0.09178 0.6499	0.22195 0.2659	0.54985 0.0030	0.30101 0.1244	0.38563 0.0470	0.35736 0.0673	0.53419 0.0041
OX2	0.67794 0.0001	1.00000 0.0000	0.41374 0.0319	0.87035 0.0001	0.39041 0.0501	0.04745 0.8142	0.19927 0.3190	0.11443 0.5698	0.23811 0.2317	0.05296 0.7931	0.01901 0.9250	0.00691 0.9727	0.35343 0.0705
OX3	0.11297 0.1349	0.41374 0.0319	1.00000 0.0000	0.08821 0.6617	0.26407 0.1832	0.06640 0.7421	0.03130 0.8769	0.05262 0.7943	0.09763 0.6281	0.06536 0.7460	0.07776 0.6999	0.07360 0.7152	0.09718 0.6654
O23	0.63734 0.0004	0.87035 0.0001	0.08821 0.6617	1.00000 0.0000	0.27339 0.1677	0.01600 0.9369	0.20110 0.3145	0.09674 0.6312	0.31333 0.1115	0.02259 0.9110	0.06286 0.7554	-0.03225 0.8731	0.43386 0.0238
NO3N	0.61908 0.0006	0.39041 0.0503	0.26407 0.1832	0.27339 0.1677	1.00000 0.0000	0.49156 0.0092	0.25112 0.2064	0.39799 0.0399	0.68891 0.0001	0.43453 0.0104	0.56744 0.0020	0.53980 0.0037	0.59974 0.0010
AIR1	0.30979 0.1159	0.04745 0.8142	0.06640 0.7421	0.01600 0.9369	0.49156 0.0092	1.00000 0.0000	0.91254 0.0001	0.98410 0.0001	0.70241 0.0001	0.99990 0.0001	0.98503 0.0001	0.93441 0.0001	0.27611 0.1633
AIR2	0.09178 0.6499	0.19927 0.3190	0.03130 0.8768	0.20110 0.3145	0.25112 0.2064	0.91254 0.0001	1.00000 0.0000	0.97068 0.0001	0.34987 0.0716	0.91836 0.0001	0.82836 0.0001	0.86424 0.0001	0.14113 0.4826
AIR3	0.22195 0.2659	0.11443 0.5698	0.05262 0.7943	0.09674 0.6312	-0.39799 0.0398	0.98410 0.0001	0.97069 0.0001	1.00000 0.0000	0.56481 0.0022	0.98656 0.0001	0.93974 0.0001	0.95984 0.0001	0.10099 0.6162
AIR4	0.54985 0.0030	0.23811 0.2317	0.09763 0.6281	0.31333 0.1115	-0.68891 0.0001	0.70241 0.0001	0.34987 0.0736	0.56481 0.0022	1.00000 0.0000	0.69205 0.0001	0.81461 0.0001	0.77165 0.0001	0.87804 0.0001
SOL1	0.30101 0.1244	0.05296 0.7931	-0.06536 0.7460	0.02259 0.9110	0.43453 0.0104	0.99990 0.0001	0.91836 0.0001	0.98656 0.0001	0.69205 0.0001	1.00000 0.0000	0.98243 0.0001	0.99278 0.0001	0.26219 0.1964
SOL2	0.38563 0.0470	0.01901 0.9250	0.07776 0.6999	-0.06286 0.7554	-0.56744 0.0020	0.98503 0.0001	0.92836 0.0001	0.93874 0.0001	0.81461 0.0001	0.98243 0.0001	1.00000 0.0000	0.99772 0.0001	0.41763 0.0224
SOL3	0.35736 0.0673	0.00691 0.9727	0.07360 0.7152	0.03225 0.8731	0.53980 0.0037	0.93441 0.0001	0.86424 0.0001	0.95984 0.0001	0.77365 0.0001	0.99278 0.0001	0.99772 0.0001	1.00000 0.0000	0.37607 0.0532
SOL4	0.53419 0.0041	0.35343 0.0705	0.09718 0.6654	0.43386 0.0238	0.59974 0.0010	0.27611 0.1633	0.14113 0.4826	0.10099 0.6162	0.87804 0.0001	0.26219 0.1864	0.41769 0.0224	0.37607 0.0532	1.00000 0.0000
SOL5	0.55627 0.0026	0.31921 0.1096	0.09385 0.6415	-0.40003 0.0387	0.65233 0.0002	0.44999 0.0185	0.04539 0.8221	0.29420 0.1508	0.95171 0.0001	0.43703 0.0226	0.59722 0.0010	0.54178 0.0035	0.98257 0.0001
SOL6	0.55983 0.0024	0.30092 0.1272	0.09573 0.6348	0.38103 0.0499	0.66809 0.0001	0.52053 0.0054	0.12579 0.5319	0.36059 0.0646	0.97337 0.0001	0.50813 0.0068	0.65994 0.0002	0.60779 0.0008	0.95439 0.0001
SOL7	0.55753 0.0025	0.31469 0.1099	0.09440 0.6395	0.39537 0.0412	0.65681 0.0002	0.46997 0.0137	0.06616 0.7430	0.30409 0.1231	0.95789 0.0001	0.45565 0.0169	0.61378 0.0007	0.53915 0.0024	-0.97049 0.0001
SOL8	0.27959 0.1578	0.36248 0.0632	0.03449 0.9644	0.41526 0.0312	0.21282 0.2865	0.44607 0.0197	0.77310 0.0001	0.59795 0.0010	0.32371 0.0995	0.45896 0.0160	-0.28509 0.1495	0.34906 0.0741	0.73734 0.0001

	OX	OX2	OX3	OX2 3	NO3N	AIR1	AIR2	AIR3	AIR4	OL1	OL2	H	OL1
BT	0 1411 0 4763	0 16761 0 4033	0 03383 0 8836	0 16185 0 4199	0 11011 0 1154	0 94683 0 0001	0 99563 0 0001	0 99393 0 0001	0 43608 0 0230	0 75139 0 0001	0 87739 0 0001	0 907 7 0 0001	0 01773 0 4121
BB2	0 33387 0 0888	0 02736 0 8922	0 07007 0 7284	0 00796 0 9685	0 51623 0 0058	0 99362 0 0001	0 88981 0 0001	0 97341 0 0001	0 73981 0 0001	0 99776 0 0001	0 39272 0 0001	0 93858 0 0001	0 32613 0 0963
BB3	0 22 50 0 7581	0 11189 0 5784	0 05319 0 7922	0 09366 0 6422	0 40187 0 0377	0 98530 0 0001	0 96899 0 0001	0 99998 0 0001	0 57050 0 0019	0 98767 0 0001	0 94110 0 0001	0 96175 0 0001	0 10797 0 5923
BB4	0 20612 0 3023	0 34010 0 0826	0 02085 0 9178	0 38339 0 0484	0 11539 0 5666	0 57131 0 0019	0 85702 0 0001	0 70402 0 0001	0 19787 0 3612	0 58312 0 0014	0 42126 0 0286	0 48145 0 0110	0 63104 0 0001
BF	0 47443 0 0124	0 11368 0 5724	0 09000 0 6551	0 17306 0 3880	0 64668 0 0003	0 91141 0 0001	0 66340 0 0002	0 82382 0 0001	0 93308 0 0001	0 90537 0 0001	0 96871 0 0001	0 94977 0 0001	0 64715 0 0003
JB	0 51592 0 0059	0 17067 0 3947	0 09489 0 6378	0 23806 0 2318	0 67628 0 0001	0 83428 0 0001	0 53582 0 0040	0 72308 0 0001	0 97844 0 0001	0 82622 0 0001	0 91684 0 0001	0 88784 0 0001	0 76026 0 0001
WSP	0 45647 0 0167	0 09234 0 6469	0 08766 0 6637	0 14845 0 4599	0 63190 0 0004	0 93361 0 0001	0 70542 0 0001	0 85512 0 0001	0 91080 0 0001	0 92033 0 0001	0 98140 0 0001	0 96623 0 0001	0 60214 0 0009
AIR1SQ	0 32189 0 1016	0 03747 0 8529	0 06825 0 7352	0 00407 0 9839	0 50401 0 0074	0 99966 0 0001	0 90154 0 0001	0 97912 0 0001	0 72078 0 0001	0 99918 0 0001	0 98920 0 0001	0 99683 0 0001	0 30119 0 1263
AIR2SQ	0 09017 0 6547	0 20023 0 3167	0 03103 0 8779	0 20229 0 3116	0 24925 0 2099	0 91134 0 0001	1 00000 0 0001	0 96997 0 0001	0 34714 0 0761	0 91720 0 0001	0 82672 0 0001	0 86277 0 0001	0 14402 0 4736
AIR3SQ	0 23133 0 2457	0 10770 0 5929	0 05412 0 7886	0 08857 0 6604	0 40822 0 0345	0 98718 0 0001	0 96611 0 0001	0 99983 0 0001	0 57982 0 0015	0 98939 0 0001	0 94489 0 0001	0 96481 0 0001	0 11913 0 5538
AIR4SQ	0 54851 0 0031	0 23444 0 2392	0 09759 0 6282	0 30929 0 1164	0 68899 0 0001	0 71098 0 0001	0 36119 0 0642	0 57476 0 0017	0 99993 0 0001	0 70074 0 0001	0 82157 0 0001	0 78127 0 0001	-0 87219 0 0001
SOL1SQ	0 31049 0 1150	0 04688 0 8164	0 06651 0 7417	0 01532 0 9395	-0 49228 0 0091	1 00000 0 0001	0 91193 0 0001	0 98383 0 0001	0 70347 0 0001	0 99987 0 0001	0 98528 0 0001	0 99456 0 0001	0 27754 0 1610
SOL2SQ	0 39335 0 0424	0 02637 0 8961	0 07888 0 6957	0 07151 0 7230	0 57483 0 0017	0 98154 0 0001	0 81747 0 0001	0 93196 0 0001	0 82550 0 0001	0 97867 0 0001	0 99982 0 0001	0 99625 0 0001	0 45484 0 0171
SOL3SQ	0 36516 0 0611	0 00010 0 9996	0 07476 0 7109	0 04054 0 8409	0 54752 0 0031	0 99232 0 0001	0 85493 0 0001	0 95456 0 0001	0 78508 0 0001	0 99042 0 0001	0 99879 0 0001	0 99983 0 0001	0 39290 0 0426
SOL4SQ	0 51685 0 0058	0 36556 0 0608	0 08287 0 6811	0 44480 0 0201	0 56684 0 0021	0 18864 0 3460	0 22950 0 2495	0 01120 0 9558	0 83149 0 0001	0 17443 0 3842	0 35513 0 0691	0 29130 0 1404	0 99595 0 0001
SOL5SQ	0 55759 0 0025	0 31444 0 1102	0 09442 0 6394	0 39512 0 0414	0 65704 0 0002	0 46945 0 0135	0 06727 0 7388	0 30514 0 1217	0 95821 0 0001	0 45664 0 0166	0 61465 0 0007	0 56007 0 0024	0 97825 0 0001
SOL6SQ	0 56014 0 0024	0 29630 0 1334	0 09608 0 6335	0 37616 0 0531	0 67119 0 0001	0 53675 0 0039	0 14472 0 4714	0 37833 0 0517	0 97757 0 0001	0 52449 0 0050	0 67418 0 0001	0 62285 0 0005	0 9 915 0 0001
SOL7SQ	0 55956 0 0025	0 30999 0 1156	0 09490 0 6377	0 39051 0 0440	0 66103 0 0002	0 48690 0 0100	0 08708 0 6658	0 32401 0 0992	0 96371 0 0001	0 47423 0 0125	0 63020 0 0004	0 57642 0 0017	0 97394 0 0001

	N	OX	OX3	OX2_3	NO3N	AIR1	AIR2	AIR3	AIR4	SOL1	[illegible]	[illegible]	[illegible]
OL3SQ	0 14853 0 4597	0 11873 0 1051	0 01040 0 9339	0 35437 0 0697	0 04129 0 8391	0 65679 0 0002	0 90775 0 0001	0 74029 0 0011	0 07539 0 7096	0 66762 0 0001	0 51695 0 0011	0 7148 0 0118	0 4341 0 1034
NH1SQ	0 14095 0 4832	0 16902 0 3994	0 03947 0 8450	0 16358 0 4149	0 30761 0 1185	0 94552 0 0001	0 99394 0 0001	0 99931 0 0001	0 43242 0 0243	0 95013 0 0001	0 87523 0 0001	0 90585 0 0001	0 05193 0 7974
NH2SQ	0 32357 0 0997	0 03606 0 8583	0 06851 0 7342	0 00239 0 9906	0 51 74 0 0071	0 99956 0 0001	0 99994 0 0001	0 97836 0 0001	0 72333 0 0001	0 99902 0 0001	0 98973 0 0001	0 99712 0 0001	0 39465 0 1223
NH3SQ	0 21880 0 2729	0 11668 0 5622	0 05212 0 7963	0 09947 0 6216	0 39454 0 0417	-0 98299 0 0001	0 97213 0 0001	0 99998 0 0001	0 55975 0 0024	0 98554 0 0001	0 93661 0 0001	0 95310 0 0001	0 09491 0 6377
NH4 Q	0 19386 0 3326	0 33581 0 0868	0 01861 0 9266	0 37749 0 0522	0 09944 0 6217	0 59039 0 0012	0 86886 0 0001	0 72437 0 0001	0 15978 0 4260	0 60200 0 0009	0 44240 0 0209	0 50186 0 0077	0 61273 0 0007
RPSQ	0 45435 0 0173	0 08990 0 6556	0 08738 0 6647	0 14563 0 4686	0 63010 0 0004	0 93591 0 0001	0 71002 0 0001	0 85848 0 0001	0 90809 0 0001	-0 93074 0 0001	0 98263 0 0001	0 96789 0 0001	0 59693 0 0010
SR Q	0 52043 0 0054	0 17809 0 3741	0 09537 0 6361	0 24645 0 2153	0 67897 0 0001	0 82214 0 0001	0 51740 0 0057	0 70794 0 0001	0 98268 0 0001	0 81382 0 0001	0 90798 0 0001	0 87766 0 0001	-0 77415 0 0001
WSP Q	0 47533 0 0122	0 11479 0 5686	0 09011 0 6549	0 17433 0 3845	0 64739 0 0001	0 91017 0 0001	0 66114 0 0002	0 82211 0 0001	0 93416 0 0001	0 90408 0 0001	0 96796 0 0001	0 94882 0 0001	0 64944 0 0002
SOLTN	0 55197 0 0028	0 26362 0 1840	0 05607 0 7812	0 31876 0 1051	0 70125 0 0001	0 62687 0 0005	0 25597 0 1975	0 47962 0 0114	0 99038 0 0001	0 61563 0 0006	0 75072 0 0001	0 70497 0 0001	0 91535 0 0001
SOLCA	0 59073 0 0012	0 45051 0 0184	0 03514 0 8618	0 47391 0 0125	0 67100 0 0001	0 41147 0 0330	0 03161 0 8756	0 25558 0 1982	0 88748 0 0001	0 39928 0 0391	0 55027 0 0030	0 49796 0 0082	0 92173 0 0011
SOLMG	0 58684 0 0013	0 28573 0 1485	0 06871 0 7335	-0 34979 0 0737	0 71647 0 0001	0 65603 0 0002	0 30281 0 1247	0 51711 0 0058	0 97567 0 0001	0 64551 0 0003	0 77092 0 0001	0 72875 0 0001	0 87637 0 0001
SOLK	0 45687 0 0166	0 12517 0 5339	-0 19391 0 3325	0 24184 0 2242	0 63469 0 0004	0 69738 0 0001	0 36512 0 0611	0 56847 0 0020	0 96193 0 0001	0 68772 0 0001	0 80129 0 0001	0 76352 0 0001	0 83032 0 0001
SOLNA	0 11486 0 5683	0 00227 0 9910	0 11349 0 5730	0 06387 0 7516	0 10900 0 5884	0 00036 0 9986	0 11320 0 5740	0 04937 0 8068	0 19618 0 3267	0 00434 0 9828	0 04723 0 8150	0 02879 0 8866	0 26515 0 1811
SOLP	0 21127 0 2901	0 25243 0 2040	0 12131 0 5467	0 21058 0 2917	0 20243 0 3112	0 11141 0 5801	0 08220 0 6836	0 10118 0 6156	-0 11213 0 5776	0 11071 0 5825	0 11795 0 5579	0 11581 0 5651	0 07651 0 7045

	SOL5	SOL6	SOL7	SOL8	NH1	NH2	NH3	NH4	RP	SR	WSP	AIR1SQ	AIR2SQ
OX	0 55627 0 0026	0 55983 0 0024	0 55753 0 0025	0 27959 0 1578	0 14315 0 4761	0 33187 0 0888	0 22550 0 2581	0 20612 0 3023	0 47443 0 0124	0 51582 0 0059	-0 45647 0 0167	0 32189 0 1016	0 09017 0 6547
OX2	0 31921 0 1046	0 30092 0 1272	-0 31469 0 1099	0 36248 0 0632	-0 16761 0 4033	0 02736 0 8922	0 11189 0 5784	0 34010 0 0826	0 11368 0 5724	0 17067 0 3947	-0 09234 0 6469	0 03747 0 0528	0 20023 0 3167
OX3	0 09385 0 6415	0 09573 0 6348	0 09440 0 6395	0 03449 0 8644	0 03981 0 8436	0 07007 0 7284	0 05319 0 7922	0 02085 0 9178	0 09000 0 6553	0 09489 0 6378	0 08766 0 6637	0 06825 0 7352	0 03103 0 9779

	OL5	OL6	OL7	OL8	PH1	PH2	PH3	PH4	P	SI	W	TI	?
OR2 J	0 40001	0 18103	0 19537	0 41526	0 16185	0 00796	0 09360	0 30339	0 17306	0 23806	0 14145	0 00407	0 202 3
	0 0387	0 0499	0 0412	0 0312	0 4199	0 9585	0 6422	0 0404	0 3800	0 2318	0 4599	0 9819	0 3115
NO3N	0 65?33	0 56809	0 65681	0 21282	0 31011	0 51623	0 40187	0 11539	0 64668	0 67628	0 63190	0 0401	0 1925
	0 0002	0 0001	0 0002	0 2865	0 1138	0 0058	0 0377	0 66?	0 0001	0 0001	0 0004	0 3074	0 093
AIL1	0 44993	0 52053	0 46947	0 44607	0 34681	0 99962	0 98530	1 57131	0 91141	0 834 8	0 93361	0 99966	0 91134
	0 0185	0 0054	0 0137	0 0197	0 0901	0 0001	0 0001	0 0019	0 0001	0 0001	0 0001	0 0001	0 0001
AIB2	0 04539	0 1 579	0 06616	-0 77310	0 99560	0 88981	0 96899	0 85707	0 66340	0 53582	0 70542	0 90154	1 03033
	0 8 21	0 5319	0 7430	0 0001	0 0001	0 0001	0 0001	0 0001	0 0002	0 0040	0 0001	0 0001	0 0001
AIB3	0 24420	0 36059	0 30409	0 59795	0 98891	0 97341	0 99998	0 70802	0 92382	0 72308	0 85512	0 97912	0 96997
	0 1508	0 0646	0 1231	0 0010	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001
AIB4	0 95171	0 97337	0 95789	0 32371	0 43609	0 73881	0 57050	0 18287	0 93308	0 97844	0 91080	0 72078	0 30714
	0 0001	0 0001	0 0001	0 0995	0 0230	0 0001	0 0019	0 3612	0 0001	0 0001	0 0001	0 0001	0 0761
SOL1	0 43703	0 50813	0 45565	0 45896	0 95139	0 99776	0 98767	0 59312	0 90537	0 82627	0 92833	0 99918	0 91720
	0 0226	0 0068	0 0169	0 0160	0 0001	0 0001	0 0001	0 0014	0 0001	0 0001	0 0001	0 0001	0 0001
SOL2	0 59722	0 65994	0 61378	-0 28508	-0 87719	0 99272	0 94110	0 42126	0 96871	0 91684	0 98140	0 98920	0 82672
	0 0010	0 0002	0 0007	0 1495	0 0001	0 0001	0 0001	0 0286	0 0001	0 0001	0 0001	0 0001	0 0001
SOL3	0 54178	0 60779	0 55915	0 34906	0 30757	0 99858	0 96175	0 48145	0 94977	0 88784	0 96623	0 99683	0 86277
	0 0035	0 0008	0 0024	0 0743	0 0001	0 0001	0 0001	0 0110	0 0001	0 0001	0 0001	0 0001	0 0001
SOL4	0 98257	0 96438	0 97848	0 73704	0 04778	0 32619	0 10787	0 63108	0 64715	0 76026	0 60214	0 30114	0 14402
	0 0001	0 0001	0 0001	0 0001	0 8129	0 0968	0 5923	0 0004	0 0003	0 0001	0 0009	0 1269	0 4736
SOL	1 00000	0 99674	0 99978	0 59854	-0 13876	0 49625	-0 29082	0 47586	0 77760	0 86778	0 74009	0 47317	0 04247
	0 0000	0 0001	0 0001	0 0010	0 4900	0 0085	0 1411	0 0121	0 0001	0 0001	0 0001	0 0127	0 9314
SOL6	0 99674	1 00000	0 99821	0 53200	0 21816	0 56464	0 36702	0 40339	0 82577	0 90502	0 79189	0 54267	0 12 89
	0 0001	0 0000	0 0001	0 0043	0 2743	0 0022	0 0597	0 0369	0 0001	0 0001	0 0001	0 0035	0 5414
SOL7	0 99978	0 99821	1 00000	0 58174	0 15933	0 51421	0 31067	0 45745	0 79052	0 87793	0 75391	0 49140	0 05325
	0 0001	0 0001	0 0000	0 0015	0 4273	0 0061	0 1147	0 0164	0 0001	0 0001	0 0001	0 0092	0 7543
SOL8	0 59854	0 53200	0 58174	1 00000	0 71029	0 39846	0 59240	0 98940	0 03826	0 12130	0 03578	-0 42252	0 77495
	0 0010	0 0043	0 0015	0 0000	0 0001	0 0395	0 0011	0 0001	0 8497	0 5467	0 6346	0 0281	0 0001
BH1	0 13876	0 21816	0 15933	0 71029	1 00000	0 92864	0 98788	0 80499	0 73057	0 61255	-0 76871	0 93810	-0 99533
	0 4900	0 2743	0 4273	0 0001	0 0000	0 0001	0 0001	0 0001	0 0001	0 0007	0 0001	0 0001	0 0001
BH2	0 49625	0 56464	0 51421	0 39846	0 92864	1 00000	0 97497	0 52744	0 93176	0 86208	0 95113	0 99965	0 88847
	0 0085	0 0022	0 0061	0 0395	0 0001	0 0000	0 0001	0 0047	0 0001	0 0001	0 0001	0 0001	0 0001
BH3	0 29082	0 36702	0 31067	0 59240	0 98788	0 97497	1 00000	0 70312	0 82772	0 72794	-0 85868	0 98050	0 96827
	0 1411	0 0597	0 1147	0 0011	0 0001	0 0001	0 0000	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001
BH4	0 47586	0 40339	0 45745	0 98940	0 80499	0 52744	0 70312	1 00000	0 18297	0 02414	-0 23933	-0 54967	-0 85852
	0 0121	0 0369	0 0164	0 0001	0 0001	0 0047	0 0001	0 0000	0 3610	0 9049	0 2292	0 0030	0 0001

	OL5	OL6	OL7	OL8	R11	RR2	RR3	RR4	IP		WSI	AIT1	AT 2
P	0 77760	0 12577	0 79052	0 03826	0 71037	0 93176	0 92777	0 11297	1 00000	0 3872	1 99914	0 92185	0 6 121
	0 0001	0 0001	0 0001	0 8497	0 0001	0 0001	0 0001	0 3610	0 0000	0 0001	0 0001	0 0301	0 909
SB	0 86778	0 90 02	0 87793	0 12130	0 61255	0 86209	0 72784	0 02414	0 38725	1 00000	0 97443	0 84941	0 53335
	0 0001	0 0001	0 0001	0 5467	0 3007	0 0001	0 0001	0 9049	0 0001	0 0000	0 0001	0 0001	0 001
WP	0 74008	0 79189	0 7 391	0 09578	0 76871	0 95113	0 85869	0 21933	0 99834	0 97643	1 00000	0 94266	0 70335
	0 0001	0 0001	0 0001	0 6346	0 3001	0 0001	0 0001	0 2292	0 0001	0 0001	0 0000	0 0001	0 0001
AIB1 Q	0 47317	0 54267	0 49140	0 42252	0 93810	0 99965	-0 98050	0 54967	0 92185	0 84841	0 94266	1 00000	0 330 7
	0 0127	0 0035	0 0092	0 0281	0 0001	0 0001	0 0001	0 0030	0 0001	0 0031	0 0001	0 0000	0 0031
AIB2SQ	0 04247	0 12289	0 06325	0 77495	0 93533	0 88847	0 96827	0 85852	0 66121	0 33316	0 70335	0 90027	1 00009
	0 8334	0 5414	0 7540	0 0001	0 0001	0 0001	0 0001	0 0001	0 0002	0 0042	0 0001	0 0001	0 0093
AIB3SQ	0 30170	0 37759	0 32147	0 58318	0 98604	0 97744	0 99994	0 69497	0 83406	0 73360	0 86446	0 98267	0 96535
	0 1262	0 0522	0 1020	0 0014	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001
AIB4 Q	0 94791	0 97052	0 95435	0 31223	0 44694	0 74692	0 58040	0 17095	0 93736	0 98087	0 91573	0 72312	0 35947
	0 0001	0 0001	0 0001	0 1128	0 0194	0 0001	0 0015	0 3939	0 0001	0 0031	0 0001	0 0001	0 06 3
OL1 Q	0 45131	0 52179	0 46978	0 44474	0 94636	0 99870	0 98505	0 57010	0 91202	0 83510	0 93414	0 99970	0 91073
	0 0181	0 0053	0 0134	0 0201	0 0001	0 0001	0 0001	0 0019	0 0001	0 0001	0 0001	0 0001	0 0001
SOL2SQ	0 61249	0 67423	0 62880	0 26665	0 86782	0 99023	0 93444	0 40379	0 97329	0 92433	0 98490	0 99620	0 81578
	0 0007	0 0001	0 0004	0 1788	0 0001	0 0001	0 0001	0 0367	0 0001	0 0031	0 0001	0 0001	0 0031
SOL3SQ	0 55702	0 62217	0 57418	0 33191	0 99976	0 99744	0 95660	0 46538	0 95532	0 89608	0 97077	0 99521	0 85341
	0 0026	0 0005	0 0017	0 0908	0 0001	0 0001	0 0001	0 0144	0 0001	0 0001	0 0001	0 0001	0 0001
SOL4SQ	0 96189	0 93671	0 95599	0 79478	0 13733	0 23994	0 01811	0 69822	0 57604	0 69882	0 52797	0 21424	0 23234
	0 0001	0 0001	0 0001	0 0001	0 4946	0 2290	0 9285	0 0001	0 0017	0 0001	0 0047	0 283	0 2435
SOL5SQ	0 99976	0 99827	1 00000	0 58084	0 16043	0 51516	0 31172	0 45647	0 79120	0 87846	0 75464	0 49237	0 06416
	0 0001	0 0001	0 0001	0 0015	0 4241	0 0060	0 1135	0 0167	0 0001	0 0001	0 0001	0 0091	0 7493
SOL6SQ	0 99502	0 99982	0 99688	0 51573	0 23676	0 58030	0 38473	0 38584	0 83639	0 91299	0 80342	0 55861	0 14193
	0 0001	0 0001	0 0001	0 0059	0 2344	0 0015	0 0475	0 0469	0 0001	0 0031	0 0001	0 0025	0 4804
SOL7SQ	0 99913	0 99924	0 99978	0 56455	0 18001	0 53209	0 33054	0 43870	0 80319	0 88778	0 76753	0 50957	0 08413
	0 0001	0 0001	0 0001	0 0022	0 3689	0 0043	0 0922	0 0221	0 0001	0 0001	0 0001	0 0066	0 6764
SOL8SQ	0 37787	0 30199	0 35852	0 96787	0 86447	0 61629	0 77595	0 99413	0 28831	0 13220	0 34301	0 63686	0 90837
	0 0520	0 1258	0 0663	0 0001	0 0001	0 0006	0 0001	0 0001	0 1447	0 5110	0 0798	0 0004	0 0001
BB1SQ	0 13474	0 21419	0 15533	0 71314	0 99999	0 92713	0 98724	0 80739	0 72779	0 60934	-0 76610	0 93669	0 99571
	0 5020	0 2834	0 4392	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0008	0 0001	0 0001	0 0001
BB2SQ	0 47642	0 54576	0 49461	0 41918	0 93682	0 99974	0 97977	0 54659	0 92328	0 85015	0 94388	0 99999	0 99865
	0 0120	0 0032	0 0087	0 0295	0 0001	0 0001	0 0001	0 0032	0 0001	0 0001	0 0001	0 0001	0 0001
BB3SQ	0 27833	0 15487	0 29825	0 60284	0 98981	0 97199	0 99992	0 71232	0 82034	0 71894	0 85193	0 97786	-0 97143
	0 1598	0 0693	0 1308	0 0009	0 0001	0 0001	0 0001	0 0001	0 0001	0 0031	0 0001	0 0001	0 0001

	JL	SOL4	SOL7	OL8	6H1	R ?	4H3	1 I4	P	H	[illegible]	[illegible]	AT [illegible]
RH4 Q	0.45 11	0.38184	0.43649	0.98572	0.01867	0. 4720	0.71359	0.99973	0.20596	0.04756	0.26201	0.56910	0.97030
	0.0171	0.0494	0.0728	0.0001	0.0001	0.0031	0.0001	0.0001	0.3027	0.8118	0.1069	0.0020	0.0031
BF J	0.73 68	0.78790	0.74961	0.10227	0.77286	0.75313	0.86201	0.24565	0.99734	0.97531	0.99939	0.94481	0.7973
	0.0001	0.0001	0.0001	0.6117	0.0001	0.0001	0.0001	0.2168	0.0001	0.0001	0.0001	0.0001	0.0001
JBSQ	0.87835	0.91403	0.88810	0.14279	0.59528	0.95089	0.71280	0.00 46	0.98157	0.99977	0.97153	0.93473	0.51433
	0.0001	0.0001	0.0001	0.4774	0.0011	0.0001	0.0001	0.9903	0.0001	0.0031	0.0001	0.0001	0.0053
WJPJQ	0.77949	0.82746	0.79236	-0.03525	0.72851	0.93066	0.82603	0.18001	1.00000	0.98772	0.99816	0.92368	0.65895
	0.0001	0.0001	0.0001	0.8614	0.0001	0.0001	0.0001	0.3689	0.0001	0.0001	0.0001	0.0001	0.0032
SOLTB	0.37222	0.98616	0.97642	0.41204	0.34491	0.66657	0.48564	0.27613	0.88934	0.94936	0.86214	0.6468	0.25315
	0.0001	0.0001	0.0001	0.0327	0.0781	0.0001	0.0102	0.1633	0.0001	0.0001	0.0001	0.0003	0.2026
SOLCA	0.93602	0.93210	0.93559	0.56897	0.11910	0.45505	0.26180	0.45499	0.72101	0.80695	0.68541	0.43331	0.02983
	0.0001	0.0001	0.0001	0.0020	0.5541	0.0171	0.1871	0.0171	0.0001	0.0031	0.0001	0.0240	0.9863
OLBO	0.94119	0.95912	0.94640	0.35477	0.39844	-0.69310	0.52282	0.21888	0.89557	0.94613	0.87165	0.67471	0.30010
	0.0001	0.0001	0.0001	0.0694	0.0453	0.0001	0.0052	0.2727	0.0001	0.0001	0.0001	0.0001	0.1283
OLK	0.90612	0.92932	0.91267	0.28254	0.44692	0.73124	0.57383	0.14593	0.90852	0.94749	0.88872	0.71447	0.36 52
	0.0001	0.0001	0.0001	0.1533	0.0194	0.0001	0.0019	0.4677	0.0001	0.0031	0.0001	0.0001	0.0631
SOLNA	0.24630	0.23546	0.24365	0.24716	0.09912	0.01413	0.04749	0.22671	0.11324	0.15186	0.09055	0.00686	0.11393
	0.2156	0.2371	0.2207	0.2139	0.6584	0.9442	0.8140	0.2555	0.5739	0.4496	0.6248	0.9729	0.571
OLP	0.09264	0.09863	0.09424	0.00709	0.09017	0.11375	0.10164	0.02458	0.12113	0.11919	0.12107	0.11261	0.08194
	0.6458	0.6245	0.6401	0.9720	0.6547	0.5721	0.6139	0.9031	0.5473	0.5538	0.5475	0.5760	0.6845

	AIR3SQ	AIR4SQ	SOL1SQ	SOL2SQ	SOL3SQ	SOL4SQ	SOL5SQ	OL6SQ	SOL7SQ	SOL8SQ	RH1SQ	RH2SQ	RH3SQ
OI	0.23133	0.54851	0.31049	0.39335	0.36516	0.51685	0.55759	0.56014	0.55856	0.14853	0.14095	0.32357	0.21889
	0.2457	0.0031	0.1150	0.0424	0.0611	0.0058	0.0025	0.0024	0.0025	0.4597	0.4832	0.0997	0.2729
OI2	0.10770	0.23444	0.04688	0.02637	0.00010	0.36556	0.31444	0.29630	0.30999	0.31873	0.16902	0.03606	0.11669
	0.5929	0.2392	0.8164	0.8961	0.9996	0.0608	0.1102	0.1334	0.1156	0.1051	0.3994	0.8583	0.5672
OI3	0.05412	0.09759	0.06651	-0.07888	0.07476	0.08287	0.09442	0.09608	0.09490	0.01080	0.03947	0.06851	0.05212
	0.7886	0.6282	0.7417	0.6957	0.7109	0.6811	0.6394	0.6335	0.6377	0.9589	0.8450	0.7342	0.7963
OI2 3	0.09857	0.30929	0.01532	0.07151	0.04054	0.44480	0.39512	0.37616	0.39051	0.35437	0.16358	0.00239	0.09947
	0.6604	0.1164	0.9395	0.7230	0.8409	0.0201	0.0414	0.0531	0.0440	0.0697	0.4149	0.9906	0.6215
NOJN	0.40822	0.68899	0.49228	0.57483	0.54752	0.56684	0.65704	0.67119	0.66103	-0.04120	0.30761	0.50574	0.39454
	0.0345	0.0001	0.0091	0.0017	0.0031	0.0021	0.0002	0.0001	0.0002	0.8393	0.1185	0.0071	0.0417
AIR1	0.98718	0.71098	1.00000	0.98154	0.99232	0.18864	0.46945	0.53675	0.48690	0.65679	-0.94552	0.99956	0.98299
	0.0001	0.0001	0.0001	0.0001	0.0001	0.3460	0.0135	0.0039	0.0100	0.0002	0.0001	0.0001	0.0001
AIR2	0.96611	0.36119	0.91193	0.81747	0.85493	0.22950	0.06727	0.14472	0.08708	0.90775	0.99598	0.89994	0.97213
	0.0001	0.0642	0.0001	0.0001	0.0001	0.2495	0.7388	0.4714	0.6658	0.0031	0.0001	0.0001	0.0001

	I I)	AI 4 2	OL15O	OL2 O	OL3)	OL45O	OL55O	SOL6 O	SOL7O	JL1 (	RH1)		(I)
AIN3	0 99993	0 7476	0 98303	0 93196	0 93456	0 01120	0 30514	0 37833	0 32401	0 78024	0 94131	0 72116	0 93911
	0 0001	0 0017	0 0001	0 0001	0 0001	0 9559	0 1217	0 0 17	0 0392	0 0001	0 0001	0 0001	0 0011
AIN4	0 37982	0 99993	0 70347	0 82558	0 78501	0 83149	0 95821	0 97757	0 96371	0 07539	0 43242	0 72333	0 97
	0 0015	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 7036	0 0243	0 0001	0 0024
SOL1	0 98939	0 70074	0 99987	0 97867	0 99042	0 17443	0 45664	0 52449	0 47423	0 66762	0 95013	0 99902	0 94551
	0 0001	0 0001	0 0001	0 0001	0 0001	0 3842	0 0165	0 0050	0 0125	0 0011	0 0011	0 0001	0 0011
SOL2	0 94499	0 92157	0 98529	0 99982	0 99979	0 35513	0 6146	0 67418	0 63020	0 51695	0 87 23	0 98973	0 93651
	0 0001	0 0001	0 0001	0 0001	0 0001	0 0691	0 0007	0 0001	0 0004	0 00 8	0 0001	0 0001	0 0001
SOL3	0 96481	0 78127	0 99456	0 99625	0 93981	0 29130	0 56007	0 62285	0 57642	0 57308	0 90585	0 99712	0 95813
	0 0001	0 0001	0 0001	0 0001	0 0001	0 1404	0 0024	0 0005	0 0017	0 0018	0 0001	0 0001	0 0011
SOL4	0 11919	0 87219	0 27754	0 45484	0 39290	0 99596	0 97825	0 95915	0 97394	0 54341	0 05193	0 30465	0 09411
	0 5538	0 0001	0 1610	0 0171	0 0426	0 0001	0 0001	0 0001	0 0001	0 0034	0 7974	0 1223	0 5377
SOL5	0 30170	0 94793	0 45131	0 61248	0 55702	0 96189	0 99976	0 99502	0 99913	0 37787	0 13474	0 47642	0 27833
	0 1262	0 0001	0 0181	0 0007	0 0026	0 0001	0 0001	0 0001	0 0001	0 0520	0 5028	0 0120	0 1599
SOL6	0 37759	0 97052	0 52179	0 67423	0 62217	0 93671	0 99827	0 99982	0 99924	0 10199	0 21419	0 54576	0 35497
	0 0522	0 0001	0 0053	0 0001	0 0005	0 0001	0 0001	0 0001	0 0001	0 1258	0 2834	0 0032	0 0693
SOL7	0 32147	0 95435	0 46978	0 62880	0 57419	0 95599	1 00000	0 99688	0 99978	0 35852	0 15533	0 49461	0 29875
	0 1020	0 0001	0 0134	0 0004	0 0017	0 0001	0 0001	0 0001	0 0001	0 0663	0 4392	0 0087	0 1308
SOL8	0 58318	0 31223	0 44474	0 26665	0 33191	0 79478	0 58084	0 51573	0 56455	0 96787	0 71314	0 41918	0 60284
	0 0014	0 1128	0 0701	0 1798	0 0908	0 0001	0 0015	0 0059	0 0022	0 0001	0 0001	0 0295	0 0009
RB1	0 98604	0 48698	0 94636	0 86782	0 89976	0 13733	0 16043	0 23676	0 18001	0 86447	0 99999	0 93682	0 99941
	0 0001	0 0194	0 0001	0 0001	0 0001	0 4946	0 4241	0 2344	0 3689	0 0001	0 0001	0 0001	0 0001
RB2	0 97744	0 74692	0 99870	0 99023	0 99744	0 23994	-0 51516	0 58030	0 53209	0 61629	0 92713	0 99974	0 97193
	0 0001	0 0001	0 0001	0 0001	0 0001	0 2280	0 0060	0 0015	0 0043	0 0006	0 0001	0 0001	0 0001
RB3	0 99994	0 58040	0 98505	0 93444	0 95660	0 01811	0 31172	0 38473	0 33054	0 77595	0 98724	0 97977	0 99992
	0 0001	0 0015	0 0001	0 0001	0 0001	0 9 85	0 1135	0 0475	0 0922	0 0001	0 0001	0 0001	0 0011
RB4	0 69497	0 17095	0 57010	-0 40379	0 46538	0 69822	0 45647	0 38584	0 43870	0 99413	0 80739	0 54659	0 7121
	0 0001	0 3939	0 0019	0 0367	0 0144	0 0001	0 0167	0 0468	0 0221	0 0001	0 0001	0 0032	0 0001
RF	0 83406	0 93736	0 91202	0 97329	0 95532	0 57604	0 79120	0 83639	0 80319	0 28831	0 72779	0 92328	0 82034
	0 0001	0 0001	0 0001	0 0001	0 0001	0 0017	0 0001	0 0001	0 0001	0 1447	0 0001	0 0001	0 0011
SB	0 73560	0 98087	0 83510	0 92433	0 89608	0 69882	0 87846	0 91299	0 88778	0 13220	0 60934	0 85035	0 71814
	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 5110	0 0008	0 0001	0 0001
WSP	0 86446	0 91573	0 93434	0 98490	0 97077	0 52797	0 75464	0 80342	0 76753	0 34301	0 76610	0 94388	0 85193
	0 0001	0 0001	0 0001	0 0001	0 0001	0 0047	0 0001	0 0001	0 0001	0 0798	0 0001	0 0001	0 0001
AIN1SQ	0 38267	0 72912	0 99970	0 98620	0 99521	0 21424	0 93237	0 55861	0 50957	0 63686	0 93669	0 99999	0 97785
	0 0001	0 0001	0 0001	0 0001	0 0001	0 2932	0 0091	0 0025	0 0066	0 0004	0 0001	0 0001	0 0011

	AIB3SQ	AIB4SQ	SOL1SQ	SOL2SQ	SOL3SQ	SOL4SQ	SOL5SQ	SOL6SQ	SOL7SQ	SOL8SQ	BH1Q	BH2SQ	BH3Q
AIR Q	0 96536	0 35847	0 91073	0 81578	0 85141	0 23 39	0 06436	1 11183	0 08418	0 90897	0 99571	0 09466	0 97141
	0 0001	0 0661	0 0001	0 0001	0 0001	0 2435	0 7498	0 4004	0 6764	0 0001	0 0001	0 0001	0 0001
AIB3SQ	1 00000	0 58964	0 98694	0 93844	0 95985	0 02950	0 32252	1 39521	0 34127	0 76872	0 98536	0 38198	0 91970
	0 0000	0 0012	0 0001	0 0001	0 0001	0 8839	0 1009	0 0413	0 081	0 0001	0 0001	0 0001	0 0001
AIB4SQ	0 58964	1 00000	0 71202	0 83235	0 79252	0 82471	0 95468	0 97495	0 96040	0 06311	0 44331	-0 73163	0 56974
	0 0012	0 0000	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 7537	0 0205	0 0001	0 0019
SOL1SQ	0 98694	0 71202	1 00000	0 98182	0 99250	0 19010	0 47076	0 53800	0 48820	-0 65567	0 94504	0 99960	0 98272
	0 0001	0 0001	0 0000	0 0001	0 0001	0 3422	0 0132	0 0038	0 0098	0 0002	0 0001	0 0001	0 0001
SOL2SQ	0 93844	0 83235	0 98182	1 00000	0 99766	0 37299	0 62966	0 69821	0 64497	0 50044	0 86500	0 98681	-0 97972
	0 0001	0 0001	0 0001	0 0000	0 0001	0 0553	0 0004	0 0001	0 0003	0 0079	0 0001	0 0001	0 0001
SOL3SQ	0 95985	0 79252	0 99250	0 99766	1 00000	0 30869	0 57509	0 63701	0 59123	0 55845	0 89798	0 99557	0 95272
	0 0001	0 0001	0 0001	0 0001	0 0000	0 1172	0 0017	0 0004	0 0012	0 0025	0 0001	0 0001	0 0001
SOL4SQ	0 02950	0 82471	0 19010	0 37299	0 30869	1 00000	-0 95566	0 92985	0 94962	0 61664	0 14135	0 21784	0 00508
	0 8839	0 0001	0 3422	0 0553	0 1172	0 0000	0 0001	0 0001	0 0001	0 0006	0 4819	0 2750	0 9799
SOL5SQ	0 32252	0 95468	0 47076	0 62966	0 57509	0 95566	1 00000	0 99697	0 99980	0 35749	0 15642	0 49557	0 29931
	0 1008	0 0001	0 0132	0 0004	0 0017	0 0001	0 0000	0 0001	0 0001	0 0671	0 4359	0 0086	0 1293
SOL6SQ	0 39521	0 97495	0 53800	0 68821	0 63701	0 92985	0 99697	1 00000	0 99832	0 28372	-0 23282	0 56167	-0 37266
	0 0413	0 0001	0 0038	0 0001	0 0004	0 0001	0 0001	0 0000	0 0001	0 1515	0 2425	0 0023	0 0556
SOL7SQ	0 34127	0 96040	0 48820	0 64497	0 59123	0 94962	0 99980	0 99832	1 00000	0 33886	0 17602	0 51273	0 31821
	0 0815	0 0001	0 0098	0 0003	0 0012	0 0001	0 0001	0 0001	0 0000	0 0838	0 3798	0 0062	0 1057
SOL8SQ	0 76872	0 06331	0 65567	0 50044	0 55845	0 61664	0 35749	0 28372	0 33886	1 00000	0 86650	0 63401	0 78410
	0 0001	0 7537	0 0002	0 0079	0 0025	0 0006	0 0671	0 1515	0 0838	0 0000	0 0001	0 0004	0 0001
BH1 Q	0 98536	0 44331	0 94504	0 86580	0 89798	0 14135	0 15642	0 23282	0 17602	0 86650	1 00000	0 93539	0 98923
	0 0001	0 0206	0 0001	0 0001	0 0001	0 4819	0 4359	0 2425	0 3798	0 0001	0 0000	0 0001	0 0001
BH2SQ	0 98198	0 73163	0 99960	-0 98681	0 99557	0 21784	-0 49557	0 56167	0 51273	0 63401	0 93539	1 00000	0 97703
	0 0001	0 0001	0 0001	0 0001	0 0001	0 2750	0 0086	0 0023	0 0062	0 0004	0 0001	0 0000	0 0001
BH3 Q	0 99970	0 56974	0 98272	0 92972	0 95272	0 00508	0 29931	0 37266	0 31821	0 78410	0 98921	0 97708	1 00000
	0 0001	0 0019	0 0001	0 0001	0 0001	0 9799	0 1293	0 0556	0 1057	0 0001	0 0001	0 0001	0 0000
BH4SQ	0 71163	0 14782	0 58919	0 42512	-0 48600	0 68125	0 43549	0 36411	0 41752	0 99639	0 82099	0 56606	0 72853
	0 0001	0 4619	0 0012	0 0271	0 0102	0 0001	0 0232	0 0619	0 0302	0 0001	0 0001	0 0021	0 0001
BPSQ	0 86772	0 91309	0 93645	0 98601	0 97231	0 52203	0 75035	0 79952	0 76334	0 34912	0 77028	0 94601	0 85533
	0 0001	0 0001	0 0001	0 0001	0 0001	0 0052	0 0001	0 0001	0 0001	0 0743	0 0001	0 0001	0 0001
SB Q	0 72074	0 98485	0 82298	0 91584	0 88625	0 71416	0 88861	0 92161	0 89755	0 11068	0 59201	0 83875	0 70360
	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 5826	0 0012	0 0001	0 0001
WS1SQ	0 83239	0 93841	0 91078	0 97259	0 95441	0 57850	0 79304	0 83804	0 90498	0 28542	0 72572	0 92212	0 81861
	0 0001	0 0001	0 0001	0 0001	0 0001	0 0016	0 0001	0 0001	0 0001	0 1490	0 0001	0 0001	0 0001

	AT 7 O	AIPHSY	OLI^Q	SOL2SQ	SJL3 O	OL4SQ	OLSS	OLC U	SJL7JJ	OL4SL	II	I I	II I
ULIH	0 41 50	0 98913	0 62801	0 76310	0 71766	0 87718	0 97664	0 98352	0 90023	0 17103	0 34112	0 64963	0 47423
	0 0086	0 0001	0 0005	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 3917	0 0416	0 000	0 0124
SOLCA	0 27201	0 88381	0 41272	0 56469	0 51234	0 90332	0 93556	0 93028	0 93475	0 36377	0 11533	0 43636	0 2 005
	0 1699	0 0001	0 0324	0 0022	0 0063	0 0001	0 0001	0 0001	0 0001	0 0621	0 5669	0 0229	0 099
SOLMG	0 51218	0 97510	0 65711	0 78227	0 74049	0 83412	0 94667	0 96243	0 95124	0 11459	0 30480	0 67731	0 51293
	0 0043	0 0001	0 0002	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 5691	0 0475	0 0001	0 00 3
SOLK	0 58259	0 96223	0 69836	0 81136	0 77408	0 78290	0 91301	0 93393	0 91898	0 04211	0 44346	0 71 85	0 56371
	0 0014	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 8348	0 0205	0 0001	0 0022
SOLNA	0 04439	0 19382	0 00005	0 05243	0 03179	0 27096	0 24351	0 23266	0 24088	0 20834	0 09018	0 03787	0 05133
	0 9260	0 3327	0 9998	0 7951	0 8671	0 1716	0 2210	0 2429	0 2261	0 2970	0 6546	0 9689	0 8004
SOLP	0 10239	0 11268	0 11148	0 11845	0 11694	0 06776	0 09433	0 09996	0 09582	0 03728	0 08984	0 11278	0 10077
	0 6113	0 5759	0 5799	0 5562	0 5630	0 7370	0 6398	0 6198	0 6345	0 853	0 6559	0 5754	0 6173

	BH4SQ	BPSQ	SBSQ	WSPSQ	SOLTW	SOLCA	SOLM	SOLK	SOLNA	SOLP
OI	0 19386	0 45435	0 52043	-0 47533	0 55197	0 59073	0 58684	0 45687	0 11486	0 21127
	0 3326	0 0173	0 0054	0 0122	0 0029	0 0012	0 0013	0 0166	0 5693	0 2901
OI2	0 33581	0 08990	0 17809	0 11479	0 26362	0 45051	-0 28573	0 12517	0 00227	0 25243
	0 0868	0 6556	0 3741	0 5686	0 1840	0 0184	0 1485	0 339	0 9910	0 2040
OI3	0 01861	0 08738	0 09537	0 09011	0 05607	0 03514	0 06871	0 19391	0 11349	0 12131
	0 9266	0 6647	0 6361	0 6549	0 7812	0 8618	0 7335	0 3325	0 5730	0 5467
OI2_3	0 37749	0 14563	0 28645	-0 17433	0 31876	0 47391	-0 34979	0 24184	0 06387	0 21058
	0 0522	0 4686	0 2153	0 3845	0 1051	0 0125	0 0737	0 2242	0 7516	0 2917
NOJB	0 09944	0 63010	0 67897	0 64739	0 70125	0 67100	0 71647	0 63468	0 10900	0 20243
	0 6217	0 0004	0 0001	0 0003	0 0001	0 0001	0 0001	0 0004	0 5884	0 3112
AIB1	0 59039	0 93593	0 82214	0 91017	0 62687	0 41147	0 65603	0 69738	0 00036	0 11141
	0 0012	0 0001	0 0001	0 0001	0 0005	0 0330	0 0002	0 0001	0 9986	0 5801
AIB2	0 86886	0 71002	0 51740	0 66114	0 25597	0 03161	0 30281	0 36512	0 11320	0 08220
	0 0001	0 0001	0 0057	0 0002	0 1975	0 8756	0 1247	0 0611	0 5740	0 6836
AIB3	0 72437	0 85848	0 70794	0 82211	0 47962	0 25558	0 51711	0 56847	0 04937	0 10118
	0 0001	0 0001	0 0001	0 0001	0 0114	0 1982	0 0059	0 0020	0 8068	0 6156
AIB4	0 15978	0 90809	0 98268	0 93416	0 99038	0 88748	0 97567	0 96193	0 19618	0 11213
	0 4260	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 3267	0 5776
SOL1	0 60200	0 93074	0 81382	0 90408	0 61563	0 39928	0 64551	0 68772	0 00434	0 11071
	0 0009	0 0001	0 0001	0 0001	0 0006	0 0391	0 0003	0 0001	0 9828	0 5825
SOL2	0 44240	0 98263	0 90798	0 96796	0 75072	0 55027	0 77097	0 80129	0 04723	0 11795
	0 0209	0 0001	0 0001	0 0001	0 0001	0 0030	0 0001	0 0001	0 8150	0 5579

	?HHSQ	RPSJ	SRSJ	HJP O	SOIL?	OICA	LM	LK	SOLNA	OLP
OLJ	0 50136	0 96789	0 87766	0 94882	0 70897	0 43796	0 7287	) 76152	0 0 879	0 11511
	J 0077	0 0001	0 0001	0 0001	0 0001	0 0092	0 0001	) 0001	0 8866	0 56 [illegible]
SOL4	0 61271	0 9693	0 77416	0 64944	0 91585	0 92173	0 87637	0 83002	0 26 [illegible]15	0 07651
	0 0007	0 0010	0 0001	0 0002	0 0001	0 0001	0 0001	0 0001	0 1413	0 7045
SOL5	0 45511	0 73568	0 87835	0 77949	0 97222	0 33602	0 94119	0 90612	0 24630	0 09764
	0 0171	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 2156	0 6458
SOL6	0 38184	0 78790	0 91403	0 82786	0 98616	0 93210	0 95912	0 92932	0 23546	0 09[illegible]3
	0 0494	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 2371	0 6245
SOL7	0 43649	0 74961	0 88810	0 79236	0 97642	0 91559	0 94640	0 91267	0 24365	0 09424
	0 0228	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 2207	0 6401
SOL8	0 98572	0 10227	0 14279	0 03525	0 41204	0 56897	0 35477	0 28254	0 24716	0 00779
	0 0001	0 6117	0 4774	0 8614	0 0327	0 0020	0 0694	0 1533	0 2139	0 9720
BH1	0 81867	0 77286	0 59528	0 72851	0 34491	0 11910	0 38884	0 44692	0 08912	0 09017
	0 0001	0 0001	0 0011	0 0001	0 0781	0 5541	0 0451	0 0194	0 6584	0 6547
BH2	0 54720	0 95313	0 85089	0 93066	0 66657	0 45505	0 69310	0 73124	0 01413	0 11375
	0 0031	0 0001	0 0001	0 0001	0 0001	0 0171	0 0001	0 0001	0 9442	0 5721
BH3	0 71959	0 96201	0 71280	0 82603	0 49564	0 26180	0 52282	0 57383	0 04749	0 10164
	0 0001	0 0001	0 0001	0 0001	0 0102	0 1871	0 0052	0 0018	0 8140	0 6139
BH4	0 99973	0 24565	0 00246	0 18001	0 27613	0 45499	0 21888	0 14593	0 22671	0 02458
	0 0001	0 2168	0 9903	0 3689	0 1633	0 0171	0 2727	0 4677	0 2555	0 9031
BP	0 20596	0 99794	-0 98357	1 00000	0 98934	0 72101	0 89557	0 90852	0 11324	0 12113
	0 3027	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 5739	0 5473
B	0 04756	0 97501	0 99977	0 98772	0 94906	0 80685	0 94613	0 94749	0 15186	0 11919
	0 8138	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 4496	0 5530
BSP	0 26201	0 99998	0 97153	0 99816	0 86214	0 68541	0 87165	0 88872	0 09855	0 12107
	0 1868	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 6248	0 5475
AIH1SQ	0 56910	0 94481	0 83673	0 92068	0 64685	0 43331	0 67471	0 71447	0 00686	0 11251
	0 0020	0 0001	0 0001	0 0001	0 0003	0 0240	0 0001	0 0001	0 9729	0 5760
AIH2SQ	0 87030	0 70796	0 51490	0 65895	0 25316	0 02888	0 30010	0 36252	0 11393	0 08194
	0 0001	0 0001	0 0060	0 0002	0 2026	0 8863	0 1283	0 0631	0 5715	0 6835
AIH3SQ	0 71163	0 96772	0 72074	0 83239	0 49550	0 27201	0 53218	0 58259	0 04439	0 10238
	0 0001	0 0001	0 0001	0 0001	0 0086	0 1699	0 0043	0 0014	0 8260	0 6113
AIH4SQ	0 14782	0 91309	0 98485	0 93841	0 98913	0 88381	0 97510	0 96223	0 19392	0 11268
	0 4619	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 3327	0 5758
OLISJ	0 58919	0 93645	0 82298	0 91078	0 62801	0 41272	0 65711	0 69836	0 00005	0 11180
	0 0012	0 0001	0 0001	0 0001	0 0005	0 0324	0 0002	0 0001	0 9998	0 5799

	BB4SQ	BFSQ	SBSQ	WSPSQ	SOLFM	SOLCA	SOLMG	SOLK	SOLNA	SOLP
SOL2SQ	0.92512	0.98601	0.91584	0.97259	0.76310	0.56469	0.78227	0.91136	0.05243	0.11845
	0.0271	0.0001	0.0001	0.0001	0.0001	0.0022	0.0001	0.0001	0.7951	0.5562
SOL3SQ	0.88500	0.97231	0.98625	0.95443	0.71766	0.51234	0.74049	0.77408	0.03379	0.11644
	0.0102	0.0001	0.0001	0.0001	0.0001	0.0063	0.0001	0.0001	0.8671	0.5630
SOL4SQ	0.68125	0.52243	0.71416	0.57850	0.87718	0.90332	0.83412	0.78290	0.27096	0.05776
	0.0001	0.0052	0.0001	0.0016	0.0001	0.0001	0.0001	0.0001	0.1716	0.7370
SOL5SQ	0.43549	0.75035	0.88861	0.79304	0.97664	0.93556	0.94667	0.91101	0.24351	0.09433
	0.0232	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.2210	0.6398
SOL6SQ	0.36411	0.79952	0.92161	0.83804	0.98852	0.93028	0.96245	0.93393	0.23266	0.09936
	0.0619	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.2429	0.6198
SOL7SQ	0.41752	0.76334	0.89755	0.80498	0.99023	0.93475	0.95124	0.91888	0.24088	0.09592
	0.0302	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.2251	0.6345
SOL8SQ	0.99639	0.34912	-0.11068	0.28542	0.17103	0.36377	0.11459	0.04211	0.20834	0.03728
	0.0001	0.0743	0.5826	0.1490	0.3937	0.0621	0.5693	0.8348	0.2970	0.8535
BB1SQ	0.82093	0.77028	-0.59201	0.72572	0.34112	0.11533	0.38480	0.44346	0.09018	0.08984
	0.0001	0.0001	0.0012	0.0001	0.0816	0.5668	0.0475	0.0205	0.6546	0.6559
BB2SQ	0.56606	0.94601	0.83875	-0.92212	0.64963	0.43636	0.67731	0.71685	0.00787	0.11278
	0.0021	0.0001	0.0001	0.0001	0.0002	0.0229	0.0001	0.0001	0.9689	0.5754
BB3SQ	0.72858	0.85533	-0.70360	0.81961	0.47428	0.25006	0.51203	0.56371	0.05103	0.10077
	0.0001	0.0001	0.0001	0.0001	0.0124	0.2084	0.0063	0.0022	0.8004	0.6170
BB4SQ	1.00000	0.26830	0.02590	0.20302	0.25365	0.43569	0.19652	0.12360	0.22296	0.02736
	0.0000	0.1760	0.8980	0.3098	0.2017	0.0231	0.3259	0.5391	0.2636	0.8923
BFSQ	0.26830	1.00000	0.96996	0.99774	0.85888	0.68124	0.86876	0.88629	0.09687	0.12103
	0.1760	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.6308	0.5476
SBSQ	0.02590	0.96996	1.00000	0.98410	0.95532	0.81695	0.95115	0.95092	0.15682	0.11869
	0.8980	0.0001	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.4347	0.5554
WSPSQ	0.20302	0.99774	0.98410	1.00000	0.89068	0.72280	0.89674	0.90948	0.11400	0.12112
	0.3098	0.0001	0.0001	0.0000	0.0001	0.0001	0.0001	0.0001	0.5713	0.5473
SOLFM	0.25365	0.85888	0.95532	0.89068	1.00000	0.90545	0.96661	0.94315	0.20984	0.07577
	0.2017	0.0001	0.0001	0.0001	0.0000	0.0001	0.0001	0.0001	0.2935	0.7072
SOLCA	0.43569	0.68124	0.81695	0.72280	0.90545	1.00000	0.92546	0.87219	0.23674	0.04938
	0.0231	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001	0.0001	0.2345	0.8068
SOLMG	0.19652	0.86876	0.95115	0.89674	-0.96661	0.92546	1.00000	0.96664	0.19984	0.07687
	0.1259	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001	0.3176	0.7031
SOLK	0.12360	0.88629	0.95092	0.90948	0.94315	0.87219	0.96664	1.00000	0.26078	0.12551
	0.5391	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.1889	0.5328
SOLNA	0.22296	0.09687	0.15682	0.11400	0.20984	0.23674	0.19984	0.26078	1.00000	0.02697
	0.2636	0.6308	0.4347	0.5713	0.2935	0.2345	0.3176	0.1889	0.0000	0.8938
SOLP	0.02736	0.12103	0.11869	0.12112	0.07577	0.04938	0.07687	0.12551	0.02697	1.00000
	0.8923	0.5476	0.5554	0.5473	0.7072	0.8068	0.7031	0.5328	0.8938	0.0000

Appendix D Correlation matrix of oxalates, nitrate-N concentrations and various soil and climatic variables using data from irrigated plots of amaranth experiments at three sites

	OX	OX2	OX3	OX2_3	NO3N	AIR1	AIR2	AIR3	AIR4	SOL1	SOL2	SOL3	SOL4
OX	1 00000 0 0000 25	0 46623 0 0216 24	0 23006 0 2795 24	0 66985 0 0003 24	0 69839 0 0001 24	-0 12417 0 5543 25	0 44259 0 0267 25	0 12806 0 5418 25	0 48796 0 0133 25	0 04715 0 8229 25	0 22699 0 2752 25	0 03470 0 6525 25	0 58623 0 0021 25
OX2	0 46623 0 0216 24	1 00000 0 0000 24	-0 44709 0 0285 24	0 58075 0 0029 24	0 37898 0 0745 23	0 30759 0 1437 24	0 60648 0 0017 24	0 50694 0 0115 24	0 14544 0 4977 24	0 45231 0 0265 24	0 20264 0 3423 24	0 33517 0 1094 24	0 47490 0 0190 [illegible]
OX3	0 23006 0 2795 24	0 44709 0 0285 24	1 00000 0 0000 24	0 46854 0 0209 24	0 00706 0 9745 23	0 78826 0 0001 24	-0 62931 0 0010 24	0 84408 0 0001 24	0 34869 0 0949 24	0 84506 0 0001 24	-0 71529 0 0001 24	0 80168 0 0001 24	0 19363 0 3645 [illegible]
OX2_3	0 66985 0 0003 24	0 58075 0 0029 24	0 46854 0 0209 24	1 00000 0 0000 24	0 38700 0 0681 23	0 41361 0 0445 24	0 02625 0 9031 24	0 26752 0 2063 24	-0 46099 0 0234 24	-0 32237 0 1245 24	-0 45085 0 0270 24	0 40041 0 05 5 24	0 23275 [illegible] [illegible]
NO3N	0 69838 0 0001 24	0 37898 0 0745 23	0 00706 0 9745 23	0 38700 0 0681 23	1 00000 0 0000 25	0 02298 0 9132 25	0 56698 0 0031 25	0 25597 0 2168 25	0 47447 0 0166 25	0 16886 0 4197 25	-0 14319 0 4949 25	0 01074 0 9 94 25	0 65974 0 0001 [illegible]
AIR1	0 12417 0 5543 25	0 30759 0 1437 24	0 78826 0 0001 24	0 41361 0 0445 24	0 02298 0 9132 25	1 00000 0 0000 27	0 54336 0 0034 27	0 92222 0 0001 27	0 73210 0 0001 27	0 96393 0 0001 27	0 98526 0 0001 27	0 99889 0 0001 27	[illegible] [illegible] 27
AIR2	0 44259 0 0267 25	0 60648 0 0017 24	-0 62931 0 0010 24	0 02625 0 9031 24	0 56698 0 0031 25	0 54336 0 0034 27	1 00000 0 0000 27	0 82571 0 0001 27	-0 17407 0 3852 27	0 74721 0 0001 27	0 39176 0 0433 27	[illegible] 0 0014 27	[illegible] 0 0001 [illegible]
AIR3	0 12806 0 5418 25	0 50694 0 0115 24	0 84408 0 0001 24	0 26752 0 2063 24	0 25597 0 2168 25	0 92222 0 0001 27	0 82571 0 0001 27	1 00000 0 0000 27	0 41176 0 0328 27	0 99187 0 0001 27	0 84249 0 0001 27	0 93344 0 0001 27	0 31241 0 1125 27
AIR	0 48796 0 0133 25	0 14544 0 4977 24	0 34869 0 0949 24	-0 46099 0 0234 24	0 47447 0 0166 25	0 73210 0 0001 27	0 17407 0 3052 27	0 41176 0 0329 27	1 00000 0 0000 [illegible]	0 52419 0 0050 27	0 93793 0 0001 27	0 69913 0 0001 [illegible]	[illegible] [illegible] [illegible]
SOL1	0 04715 0 8229 25	0 45231 0 0265 24	-0 84506 0 0001 24	-0 32237 0 1245 24	0 16886 0 4197 25	0 96393 0 0001 27	0 74721 0 0001 27	0 99187 0 0001 27	0 52438 [illegible] 27	1 00000 0 0000 27	0 90419 0 0001 27	[illegible] 0 0001 [illegible]	[illegible] [illegible] [illegible]
SOL2	0 2 699 0 2752 25	0 20264 0 3423 24	0 71 29 0 0001 24	0 45085 0 0270 24	0 14318 0 4949 25	0 98526 0 0001 27	0 39176 0 0433 27	0 84249 0 0001 27	0 83793 0 0001 27	0 90419 0 0001 27	1 00000 0 0000 27	[illegible] 0 0001 [illegible]	[illegible] [illegible] [illegible]
SOL3	0 03470 0 6525 25	0 33517 0 1094 24	0 80169 0 0001 24	0 40041 0 0 25 24	0 01074 0 9594 2	0 94989 0 0001 27	0 58211 0 0014 27	0 93944 0 0001 27	0 69913 0 0001 27	0 97542 0 0001 [illegible]	0 97609 [illegible] [illegible]	1 00000 0 0000 [illegible]	[illegible] [illegible] 27
SOL4	[illegible] [illegible] 2	0 47490 0 0190 24	[illegible] 0 3645 24	0 24276 [illegible] [illegible]	[illegible] 0 0001 	0 07120 [illegible] [illegible]	0 79392 0 0001 27	0 31241 [illegible] 27	[illegible] [illegible] [illegible]	[illegible] [illegible] [illegible]	[illegible] [illegible] [illegible]	[illegible] [illegible] 27	1 00000 0 0000 27

	YC	Y2	UZ3	UY2 3	4031	A181	AI	AI13	AI 4	H1	CL	I	I
U	0 58973 0 0020 2	0 44104 0 0289 24	0 11319 0 5350 24	0 31931 0 1283 24	0 55355 0 0904 25	0 16218 0 4190 27	0 7432 0 0301 27	0 23191 0 2443 27	0 79091 0 0001 27	0 10 31 0 5377 27	0 3217 0 0143 27	0 11342 0 5 5 7	0 396 1 0 3031 7
UL	0 58844 0 0020 25	0 47454 0 0387 24	0 09065 0 6736 24	0 33680 0 1073 4	0 64696 0 300 2	0 21953 0 2712 27	0 59173 0 0001 27	0 17478 0 383 27	0 12 30 0 0001 27	0 04136 0 0119 27	0 38317 0 0485 27	0 173 4 0 3175 27	0 91971 0 0031 27
SOL7	0 58942 0 0020 25	0 43356 0 0316 24	0 12017 0 5760 24	0 32476 0 1215 24	0 5173 0 0004 25	0 17984 0 3194 27	0 72809 0 0001 27	0 1451 0 2426 27	0 90175 0 0001 27	0 08847 0 6638 27	0 34545 0 0776 27	0 131 0 0 5177 27	0 994 0 3001 7
ULB	0 54083 0 0053 25	0 56548 0 0040 24	0 47758 0 0371 24	0 16935 0 4289 24	0 64478 0 0005 25	0 2 146 0 2058 27	0 9491 0 0001 27	0 60614 0 0008 27	0 47322 0 0122 27	0 50000 0 0079 27	0 08220 0 6836 27	0 29687 0 1327 7	0 94431 0 0031 27
BH1	0 01602 0 394 25	0 42887 0 0365 24	0 84063 0 0001 24	0 34149 0 1024 24	0 13475 0 5208 25	0 97570 0 0001 27	0 71409 0 0001 27	0 99453 0 0001 27	0 56506 0 0021 27	0 99892 0 0001 27	0 92385 0 0001 27	0 94196 0 0001 27	0 14113 0 4823 27
BH2	0 22092 0 2886 25	0 20922 0 3265 24	0 72046 0 0001 24	0 44906 0 0277 24	0 13597 0 5170 25	0 98701 0 0001 27	0 40145 0 0379 27	0 84813 0 0001 27	0 83202 0 0001 27	0 90865 0 0031 27	0 99994 0 0001 27	0 97033 0 0001 27	0 23833 0 2313 27
BH3	0 117 8 0 5757 25	0 31385 0 1353 24	0 79192 0 0001 24	0 41075 0 0462 24	0 01541 0 9417 25	0 99994 0 0001 27	0 55225 0 0028 27	0 92628 0 0001 27	0 72482 0 0001 27	0 96670 0 0001 27	0 98339 0 0001 27	0 99933 0 0001 27	0 06951 0 7339 27
BH4	0 55285 0 0042 25	0 27781 0 1887 24	0 16103 0 4522 24	0 42093 0 0405 24	0 57151 0 0029 25	0 53452 0 0041 27	0 41906 0 0295 27	0 16615 0 4075 27	0 96704 0 0001 27	0 29029 0 1419 27	0 67121 0 0001 27	0 49403 0 0088 27	0 88483 0 0031 27
BF	0 35254 0 0839 25	0 05401 0 8021 24	0 50032 0 0030 24	0 47481 0 0190 24	0 29637 0 1503 25	0 91724 0 0001 27	0 16394 0 4137 27	0 69187 0 0001 27	0 94286 0 0001 27	0 77813 0 0031 27	0 97186 0 0001 27	0 89741 0 0001 27	0 46974 0 0133 27
SB	0 47982 0 0152 25	0 13150 0 5402 24	0 36677 0 0779 24	0 46367 0 0225 24	0 46313 0 0197 25	0 74906 0 0001 27	0 14915 0 4578 27	0 43463 0 0235 27	0 99968 0 0001 27	0 54571 0 0032 27	0 85134 0 0001 27	0 71696 0 0001 27	0 71975 0 0031 27
BSI	0 58171 0 0023 25	0 17281 0 0728 24	0 00483 0 9821 24	0 37260 0 0730 24	0 62559 0 0008 25	0 34450 0 0785 27	0 60092 0 0009 27	0 04530 0 8225 27	0 99171 0 0001 27	0 08220 0 6836 27	0 50000 0 0079 27	0 29980 0 1287 27	0 9 312 0 3031 27
AIBIU	0 13488 0 5204 25	0 29730 0 1583 24	0 78207 0 0001 24	0 41814 0 0420 24	0 03531 0 8669 25	0 99985 0 0001 27	0 52874 0 0046 27	0 91518 0 0001 27	0 74379 0 0001 27	0 95917 0 0031 27	0 98809 0 0001 27	0 99792 0 0001 27	0 03646 0 6322 27
AIB25U	0 45117 0 0236 25	0 60541 0 0017 24	0 61648 0 0014 24	0 03688 0 8642 24	0 57499 0 0027 25	0 52452 0 0050 27	0 99975 0 0001 27	0 81293 0 0001 27	0 19598 0 3272 27	0 73221 0 0001 27	0 37116 0 0566 27	0 56412 0 0022 27	0 90719 0 0031 27

	OI	OI2	OI3	OI2 3	1314	AIP1	AIP2	AIP3	AI 4	OI 1	L	II	II I
IBI Q	0 13344	0 1023	0 84135	0 26361	7 26168	0 91086	0 83053	0 91197	0 40190	0 19074	0 81782	0 33616	0 3 0
	0 249	0 0109	0 0001	0 2133	0 2064	0 0001	0 0001	0 0001	0 0167	0 0011	0 0001	0 0031	0 1033
	25	24	24	24	25	27	27	7	27	27	27	7	27
AIB4SQ	0 43921	0 18762	0 34583	0 46054	0 476 3	0 72938	0 17719	0 40313	0 99999	0 039	0 43 63	0 61 29	0 71971
	0 0131	0 4312	0 0979	0 0235	0 0161	0 0001	0 3744	0 0146	0 0001	0 0053	0 0001	0 0001	0 0001
	25	24	24	24	2	27	27	27	27	27	27	27	27
SOL1 J	0 04715	0 45231	0 84506	0 32237	0 15985	0 96393	0 74721	0 99187	0 52438	1 00000	0 90413	0 3754	0 19993
	0 8229	0 0265	0 0001	0 1245	0 4197	0 0001	0 0001	0 0001	0 0050	0 0031	0 0001	0 0331	0 14 1
	25	24	24	24	25	27	27	27	7	27	27	27	27
SOL2 J	0 23294	0 19624	0 71020	0 45253	0 15015	0 98346	0 38231	0 83692	0 94339	0 09977	0 99995	0 97181	0 25845
	0 2627	0 3581	0 0001	0 0264	0 4738	0 0001	0 0491	0 0001	0 0001	0 0031	0 0001	0 0031	0 1933
	25	24	24	24	25	27	27	27	27	27	27	27	27
SOL3SQ	0 09863	0 33156	0 00177	0 40223	0 006 6	0 99915	0 57729	0 93728	0 70359	0 97402	0 97743	0 99998	0 03931
	0 6390	0 1135	0 0001	0 0513	0 9763	0 0001	0 0016	0 0001	0 0001	0 0001	0 0001	0 0001	0 8495
	25	24	24	24	25	27	27	27	27	27	27	27	27
SOL4SQ	0 57420	0 0741	0 26781	0 25741	0 66198	0 024 6	0 85243	0 40093	0 66324	0 28947	0 14709	0 07143	0 99464
	0 0025	0 0114	0 2058	0 2246	0 0003	0 9043	0 0001	0 0342	0 0002	0 1430	0 4641	0 7233	0 0001
	25	24	24	24	25	27	27	27	27	27	27	7	27
SOL 5Q	0 58882	0 43941	0 11988	0 32488	0 65169	0 18023	0 72782	0 21413	0 80199	0 08808	0 14582	0 13360	0 99401
	0 0020	0 0117	0 5769	0 1214	0 0004	0 3683	0 0001	0 2835	0 0001	0 6622	0 0772	0 5065	0 0031
	25	24	24	24	25	27	27	27	27	27	27	27	27
SOL6SQ	0 58804	0 41809	0 07824	0 34172	0 64469	0 23609	0 64748	0 15901	0 83478	0 03137	0 39982	0 18996	0 99733
	0 0020	0 0420	0 7163	0 1022	0 0005	0 2358	0 0001	0 4312	0 0001	0 9777	0 0393	0 3426	0 0001
	25	24	24	24	25	27	27	27	27	27	7	27	27
SOL7 Q	0 8875	0 41297	0 10711	0 33014	0 64973	0 19745	0 71568	0 19696	0 81234	0 07060	0 36222	0 15095	0 99297
	0 0020	0 0346	0 6184	0 1151	0 0004	0 3235	0 0001	0 3240	0 0001	0 7264	0 0631	0 523	0 0001
	25	24	24	24	25	27	27	27	27	27	27	27	27
SOL8SQ	0 54083	0 56348	0 42758	0 16935	0 64478	0 25146	0 94916	0 60614	0 47522	0 50000	0 08220	0 29687	0 94491
	0 0053	0 0040	0 0371	0 4289	0 0005	0 2058	0 0001	0 0008	0 0122	0 0079	0 6936	0 1327	0 0001
	25	24	24	24	25	27	27	27	27	27	27	27	27
BH1SQ	0 01798	0 41038	0 84098	0 34032	0 13690	0 97303	0 71622	0 98506	0 56255	0 99897	0 2269	0 98443	0 14414
	0 9320	0 0358	0 0001	0 1037	0 5141	0 0001	0 0001	0 0001	0 0023	0 0001	0 0001	0 0001	0 4712
	25	24	24	24	25	27	27	27	27	27	27	27	27
BH 5Q	0 19688	0 23481	0 73985	0 44143	0 10755	0 99280	0 43088	0 86925	0 80944	0 92 10	0 99866	0 98604	0 19806
	0 3455	0 2694	0 0001	0 0308	0 6089	0 0001	0 0220	0 0001	0 0001	0 0001	0 0001	0 0001	0 32 3
	25	24	24	24	25	27	27	27	27	27	27	27	27
BH3SQ	0 10507	0 32559	0 79853	0 40518	0 00109	0 99953	0 56886	0 93364	0 71086	0 97164	0 97955	0 99986	0 01859
	0 6172	0 1205	0 0001	0 0495	0 9959	0 0001	0 0020	0 0001	0 0001	0 0001	0 0001	0 0001	0 8093
	25	24	24	24	25	27	27	27	27	27	27	27	27

	OX	OX2	OX3	OX2_3	NO3N	AIR1	AIR2	AIR3	AIR4	SOL1	SOL2	SOL3	SL3
BB4SQ	0 54949 0 0045 25	0 6941 0 2030 24	0 17387 0 4165 24	0 42432 0 0348 24	0 6601 0 0012 25	0 54920 0 0030 27	0 40314 0 0371 27	0 19335 0 3600 27	0 97134 0 0001 27	0 30636 0 1194 27	0 68405 0 0001 27	0 0914 0 0067 7	0 87655 0 0001 27
8P J	0 21378 0 2607 25	0 19521 0 3607 24	0 70937 0 0001 24	0 43280 0 0263 24	0 15127 0 4704 25	0 90316 0 0001 27	0 39078 0 0501 27	0 83607 0 0001 27	0 04427 0 0001 27	0 89905 0 0001 27	0 99993 0 0001 27	0 97343 0 0001 27	0 2 005 0 1997 27
JBSQ	0 48490 0 0140 25	0 14014 0 5137 24	0 35559 0 0881 4	0 46204 0 0230 24	0 47013 0 0177 2	0 73862 0 0001 27	0 16458 0 4120 27	0 42051 0 0290 27	0 99995 0 0001 27	0 53255 0 0043 27	0 84304 0 0001 27	0 70398 0 0001 27	0 73053 0 0001 27
W P W	0 57707 0 0025 25	0 35225 0 0914 24	0 04050 0 8510 24	0 39476 0 0634 24	0 61537 0 0011 25	0 38962 0 0445 27	0 56145 0 0023 27	0 00320 0 9874 27	0 91261 0 0001 27	0 13043 0 5167 27	0 54141 0 0016 27	0 34571 0 0773 7	0 91891 0 0001 27
SOLEK	0 54322 0 0050 25	0 21247 0 3189 24	0 24754 0 2435 24	0 43513 0 0336 24	0 56678 0 0032 25	0 60038 0 0009 27	0 34179 0 0810 27	0 24600 0 2161 27	0 98158 0 0001 27	0 36693 0 0597 27	0 72764 0 0001 27	0 56215 0 0023 27	0 84078 0 0001 27
SOLCA	0 49392 0 0121 25	0 21790 0 3064 24	0 31422 0 1348 24	0 50118 0 0126 24	0 57733 0 0025 25	0 65079 0 0002 27	0 22943 0 2497 27	0 33162 0 0911 27	0 94954 0 0001 27	0 44246 0 0208 27	0 75999 0 0001 27	0 61728 0 0006 27	0 74383 0 0001 27
SO BG	0 53958 0 0055 25	0 20071 0 3470 24	0 35244 0 0912 24	0 51899 0 0094 24	0 54420 0 0049 25	0 70019 0 0001 27	0 19398 0 3323 27	0 38115 0 0498 27	0 97872 0 0001 27	0 49280 0 0090 27	0 80691 0 0001 27	0 66711 0 0001 27	0 73757 0 0001 27
SOLK	0 34541 0 0908 25	0 20800 0 3294 24	0 10329 0 6310 24	0 29944 0 1552 24	0 51043 0 0091 25	0 42326 0 0278 27	0 28619 0 1478 27	0 15759 0 4474 27	0 72972 0 0001 27	0 24434 0 2193 27	0 52220 0 0052 27	0 39377 0 0421 27	0 6364 0 0003 27
U NA	0 52915 0 0065 25	0 14967 0 4852 24	0 39355 0 0571 24	0 50599 0 0116 24	0 50246 0 0105 25	0 74280 0 0001 27	0 14469 0 4715 27	0 43249 0 0243 27	0 98070 0 0001 27	0 54216 0 0035 27	0 84356 0 0001 27	0 71114 0 0001 27	0 79990 0 0001 27
SOLP	0 277 9 0 1791 2	0 14819 0 4895 24	0 43908 0 0318 24	0 54596 0 0058 24	0 03529 0 8670 25	0 42465 0 0273 27	0 37129 0 0565 27	0 45636 0 0167 27	0 19684 0 3251 27	0 45389 0 0174 27	0 38975 0 0445 27	0 43208 0 0244 27	0 13326 0 507 27

	OL	OL6	OL7	SOLA	PH1	R12	R11	H4	HP	SR	W P	AI [illegible]	AIK [illegible]
OX	0 51873 0 00 3 2	0 8884 0 0020 25	0 59982 0 0020 25	0 54183 0 0053 25	0 01607 0 9394 2	0 2 092 0 2886 25	0 11759 0 5757 25	0 5 95 0 0042 2	0 33254 0 0839 25	0 47992 0 0152 25	0 58171 0 0023 25	0 13488 0 5 04	0 4 117 0 1235
OX	0 44E04 [illegible] 4	[illegible] 0 0347 24	0 413 6 0 01 6 24	0 56 48 0 0040 24	0 42997 0 316 4	0 20122 0 3 6 24	0 31385 0 1351 24	0 27781 0 1197 4	0 0 401 0 0321 4	0 13150 0 5402 24	0 37 81 0 07 1 4	0 29730 0 1 33 4	[illegible] 0 1017 24
CII	0 13113 [illegible] 4	0 1106 0 1736 2	0 12017 0 5710 4	0 4 734 0 0371 24	0 14061 0 0011 4	0 72016 0 0031 24	0 79192 0 0001 4	0 16101 0 1 22 1	0 51332 0 3030 4	0 16077 0 0779 24	0 00481 [illegible] 4	0 74 07 0 0001 1	0 51611 0 3014 4

	SOL5	SOL6	SOL7	SOL8	BH1	BH2	BH3	BH4	BP	SR	W	AIR1	AIR2_J
UZ2_J	0.31931 0.1283 24	0.33680 0.1075 24	0.37476 0.1215 24	0.16935 0.4289 24	0.34149 0.1024 24	0.44906 0.0277 24	0.41075 0.0462 24	0.42093 0.0405 24	0.47481 0.0190 24	0.46367 0.0225 24	0.37260 0.0730 24	0.41114 0.0420 24	0.03698 0.8642 24
NOJN	0.65355 0.0004 25	0.64696 0.0005 25	0.65173 0.0004 25	0.64478 0.0005 25	0.13475 0.5209 25	0.13597 0.5170 25	0.01541 0.9417 25	0.57151 0.0029 25	0.29637 0.1503 25	0.46313 0.0197 25	0.62559 0.1009 25	0.03531 0.8669 25	0.57493 0.00 7 25
A1B1	0.16218 0.4190 27	0.21953 0.2712 27	0.17984 0.3694 27	0.25146 0.2058 27	0.97570 0.0001 27	0.98701 0.0001 27	0.99994 0.0001 27	0.53452 0.0041 27	0.91724 0.0001 27	0.74906 0.0001 27	0.34450 0.0785 27	0.99985 0.0001 7	0.52452 0.0053 27
A1B2	0.74026 0.0001 27	0.69973 0.0001 27	0.72809 0.0001 27	0.94916 0.0001 27	0.71409 0.0001 27	0.40146 0.0379 27	0.55225 0.0028 27	0.41906 0.0296 27	0.16399 0.4137 27	0.14915 0.4578 27	0.60092 0.0009 27	0.52974 0.0046 7	0.99975 0.0001 27
A1B3	0.23193 0.2443 27	0.17478 0.3832 27	0.21451 0.2826 27	0.60614 0.0008 27	0.98453 0.0001 27	0.84813 0.0001 27	0.92628 0.0001 27	0.16615 0.4075 27	0.69187 0.0001 27	0.43463 0.0 35 27	0.04530 0.8225 27	0.91539 0.0001 27	0.81293 0.0001 27
A1B4	0.79091 0.0001 27	0.82530 0.0001 27	0.80175 0.0001 27	0.47522 0.0122 27	0.56506 0.0021 27	0.83202 0.0001 27	0.72482 0.0001 27	0.96704 0.0001 27	0.94206 0.0001 27	0.99968 0.0001 27	0.89171 0.0001 27	0.74379 0.0001 27	0.19599 0.1272 27
SOL1	0.10631 0.5977 27	0.04806 0.8119 27	0.08897 0.6608 27	0.50000 0.0079 27	0.99882 0.0001 27	0.90865 0.0001 27	0.96670 0.0001 27	0.29029 0.1419 27	0.77813 0.0001 27	0.54571 0.0032 27	0.08220 0.6836 27	0.95917 0.0001 27	0.73 21 0.0031 27
SOL2	0.32857 0.0943 27	0.38317 0.0485 27	0.34545 0.0776 27	0.08220 0.6836 27	0.92385 0.0001 27	0.99994 0.0001 27	0.98339 0.0001 27	0.67121 0.0001 27	0.97186 0.0001 27	0.85134 0.0001 27	0.50000 0.0079 27	0.98809 0.0001 27	0.37116 0.055 27
SOL3	0.11542 0.5665 27	0.17324 0.3875 27	0.13320 0.5077 27	0.29697 0.1327 27	0.98496 0.0001 27	0.97833 0.0001 27	0.99933 0.0001 27	0.49403 0.0088 27	0.89741 0.0001 27	0.71696 0.0001 27	0.29980 0.1287 27	0.93792 0.0001 27	0.56412 0.0022 27
SOL	0.996 1 0.0101 27	0.98993 0.0001 27	0.99485 0.0001 27	0.94491 0.0001 27	0.14113 0.4826 27	0.23930 0.2313 27	0.06861 0.7338 27	0.88484 0.0001 27	0.46974 0.0134 27	0.71975 0.0001 27	0.96312 0.0001 27	0.09646 0.6322 27	0.80719 0.0031 27
U 5	1.00000 0.0000 27	0.99829 0.0001 27	0.99984 0.0001 27	0.91427 0.0001 27	0.05796 0.7740 27	0.31858 0.1053 27	0.15169 0.4501 27	0.92065 0.0001 27	0.54132 0.0035 27	0.775 1 0.0001 27	0.98223 0.0001 27	0.17325 0.3710 27	0.71595 0.0001 27
SOL	[illegible] 0.1001 27	1.00000 0.0000 27	1.99918 0.0001 27	0.88305 0.0001 27	0.00045 0.998 27	0.17340 0.0550 27	0.20316 0.2951 27	0.94189 0.0001 27	0.58999 0.0012 27	0.81078 0.0001 27	0.99151 0.0001 27	0.23641 0.2352 27	0.71543 0.0001 27
OLT	[illegible] 0.1101 27	[illegible] 0.0001 27	1.00000 0.0000 27	0.90637 0.0001 27	0.14006 0.8428 27	0.335 2 0.0871 7	0.16933 0.3943 27	[illegible] 0.0001 27	0.5 630 0.0026 7	0.70641 0.0031 27	[illegible] 0.0001 27	[illegible] 0.1250 7	0.71111 0.0031 7

	OI	OLI	OL7	OL8	RH1	RH2	RH3	RH4	KP	K	WSP	A1B1Q	A1B25Q
OL8	0 11427 0 0001 27	0 8890 0 0001 27	0 90687 0 0001 27	1 00000 0 0000 27	0 4 740 0 0164 27	0 09272 0 6455 27	0 26173 0 1873 27	0 613 9 0 1091 27	0 13489 0 4404 27	0 4 21 0 0177 27	0 02193 0 0031 27	0 3465 0 387 7	0 95 14 0 0031 7
RH1	0 05716 0 7740 27	0 00045 0 9982 27	0 04006 0 8428 27	0 45740 0 0164 27	1 00000 0 0000 27	0 92784 0 0001 27	0 97799 0 0001 27	0 33637 0 0863 27	0 90758 0 0001 27	0 58571 0 0013 27	0 13044 0 5167 27	0 9717 0 0001 7	0 63031 0 0031 27
RH2	0 31858 0 1053 27	0 17340 0 0550 27	0 33352 0 0871 27	0 09272 0 6455 27	0 92784 0 0001 27	1 00000 0 0000 27	0 98525 0 0001 27	0 65334 0 0002 27	0 9 911 0 0001 27	0 44576 0 0091 27	0 41083 0 0033 27	0 98365 0 0001 27	0 31094 0 3433 7
RH3	0 15169 0 4 01 27	0 20916 0 2951 27	0 16339 0 3983 27	0 26173 0 1873 27	0 97799 0 0001 27	0 98525 0 0001 27	1 00000 0 0000 27	0 5 551 0 0049 27	0 91295 0 0001 27	0 74198 0 0001 27	0 33451 0 0881 27	0 99961 0 0001 27	0 53353 0 3042 7
RH4	0 92065 0 0001 27	0 94188 0 0001 27	0 92750 0 0001 27	0 68359 0 0001 27	0 33637 0 0861 27	0 66334 0 0002 27	0 52551 0 0049 27	1 00000 0 0000 27	0 82694 0 0001 27	0 96030 0 0001 27	0 97756 0 0001 27	0 54909 0 0030 27	0 43923 0 0219 27
KP	0 54182 0 0035 27	0 58999 0 0012 27	0 55680 0 0026 27	0 15489 0 4404 27	0 80768 0 0001 27	0 96931 0 0001 27	0 91295 0 0001 27	0 82694 0 0001 27	1 00000 0 0000 27	0 95097 0 0001 27	0 68994 0 0001 27	0 9 400 0 0001 27	-0 14136 0 4907 27
K	0 77521 0 0001 27	0 91078 0 0001 27	0 78641 0 0001 27	0 45285 0 0177 27	0 59571 0 0013 27	0 84576 0 0001 27	0 74198 0 0001 27	0 95030 0 0001 27	0 95097 0 0001 27	1 00000 0 0000 27	0 88000 0 0001 27	0 76043 0 0001 27	0 17116 0 3933 27
WSP	0 98223 0 0001 27	0 99151 0 0001 27	0 98543 0 0001 27	0 82199 0 0001 27	0 13048 0 5167 27	0 49093 0 0093 27	0 33451 0 0881 27	0 97756 0 0001 27	0 68994 0 0001 27	0 88030 0 0001 27	1 00000 0 0000 27	0 36071 0 0645 27	0 61839 0 0035 27
A1B1Q	0 17375 0 3710 27	0 23641 0 2352 27	0 19686 0 3750 27	0 23465 0 2387 27	0 97176 0 0001 27	0 98965 0 0001 27	0 99961 0 0001 27	0 54909 0 0030 27	0 92400 0 0001 27	0 76043 0 0001 27	0 36071 0 0645 27	1 00000 0 0000 27	0 50969 0 3065 27
A1B25Q	0 7 06 0 0001 27	0 71548 0 0001 27	0 74319 0 0001 27	0 95594 0 0001 27	0 69831 0 0001 27	0 38094 0 0499 27	0 53353 0 0042 27	0 43920 0 0219 27	0 14196 0 4800 27	0 17116 0 3933 27	0 61859 0 0006 27	0 50969 0 0066 27	1 00000 0 0003 27
A1B35Q	0 24035 0 2272 27	0 18325 0 3602 27	0 22292 0 2637 27	0 61297 0 0007 27	0 98298 0 0001 27	0 84354 0 0001 27	0 92300 0 0001 27	0 15766 0 4322 27	0 68563 0 0001 27	0 42696 0 0264 27	0 05390 0 7895 27	0 91188 0 0001 27	0 91794 0 0001 27
A1B45Q	0 79334 0 0001 27	0 82754 0 0001 27	0 80412 0 0001 27	0 47871 0 0115 27	0 56178 0 0023 27	0 82980 0 0001 27	0 72207 0 0001 27	0 96805 0 0001 27	0 94152 0 0001 27	0 99957 0 0031 27	0 89350 0 0001 27	0 74113 0 0001 27	0 19937 0 3175 27
SOLISQ	0 19631 0 5977 27	0 04806 0 8119 27	0 08947 0 6608 27	0 50000 0 0079 27	0 99882 0 0001 27	0 90865 0 0001 27	0 96670 0 0001 27	0 29029 0 1419 27	0 77813 0 0001 27	0 58571 0 0012 27	0 08220 0 6836 7	0 95917 0 0001 27	0 73221 0 0031 27

	CI	OL1	OL7	OL9	H1	H2	[illegible]	HH4	BF	S	W	AL C	A 2 2
OL2 Q	0 33924 0 1844 7	0 19262 0 0428 27	0 35505 0 0692 27	0 07198 0 7212 27	0 91984 0 0001 27	0 99974 0 0001 27	0 98144 0 0001 27	0 f7877 0 0001 7	0 3742 0 0001 27	0 85654 0 0031 27	1 0845 0 0067 27	0 31 5 0 0001 7	0 1 162 0 1633 27
SOL3 Q	0 12163 0 456 27	0 17940 0 3706 27	0 13940 0 4380 27	0 29088 0 1410 27	0 93386 0 0001 27	0 97961 0 0301 27	0 99954 0 0001 27	0 49946 0 0090 27	0 90016 0 0001 7	0 72130 0 0031 27	0 30576 0 1209 27	0 99930 0 0001 27	0 5 834 0 0025 27
SOL4SQ	0 98254 0 0001 27	0 96999 0 0001 27	0 97904 0 0001 27	0 97368 0 0001 27	0 24270 0 2225 27	0 13664 0 4968 27	0 03408 0 8629 27	0 83194 0 0001 27	0 37597 0 0 33 27	0 f4411 0 0093 27	0 93015 0 0001 27	0 00 94 0 7726 27	0 8 333 0 0031 27
SOL5 Q	0 99983 0 0001 27	0 99920 0 0001 27	1 00000 0 0001 27	0 90670 0 0001 27	0 03966 0 8443 27	0 33589 0 0867 27	0 16977 0 3972 27	0 92765 0 0001 27	0 55713 0 0026 27	0 78665 0 0001 27	0 98550 0 0001 27	0 197 4 0 3241 27	0 74233 0 0031 27
SOL6SQ	0 94716 0 0001 27	0 99986 0 0001 27	0 93835 0 0001 27	0 88110 0 0001 27	0 01745 0 9312 27	0 38912 0 0448 27	0 22575 0 2575 27	0 94746 0 0001 27	0 60363 0 0009 7	0 82062 0 0001 27	0 99358 0 0001 27	0 25289 0 2031 27	0 70350 0 0001 27
OL7 Q	0 93936 0 0001 27	0 99975 0 0001 27	0 99984 0 0001 27	0 89916 0 0001 27	0 02213 0 9128 27	0 35236 0 0715 27	0 18702 0 3503 27	0 93406 0 0001 27	0 57161 0 0019 27	0 79736 0 0001 27	0 98833 0 0001 27	0 21481 0 2829 27	0 73107 0 0001 27
SOL8SQ	0 91427 0 0001 27	0 9890 0 0001 27	0 90687 0 0001 27	1 00000 0 0001 27	0 45740 0 0164 27	0 09272 0 6455 27	0 26173 0 1873 27	0 68359 0 0001 27	0 15489 0 4404 27	0 45295 0 0177 27	0 82199 0 0001 27	J 23465 0 2397 27	0 9.531 0 0001 27
HH1 Q	0 06099 0 7625 27	0 00259 0 9890 27	0 04310 0 8310 27	0 46011 0 0157 27	1 00000 0 0001 27	0 92670 0 0001 27	0 97738 0 0001 27	0 33350 0 0891 27	0 80588 0 0001 27	0 58324 0 0014 27	0 12743 0 5265 27	0 97104 0 0001 27	0 70049 0 0001 27
HH2SQ	0 77923 0 1584 27	0 33493 0 0878 27	0 29639 0 1333 27	0 13369 0 5062 27	0 94243 0 0001 27	0 99915 0 0001 27	0 99147 0 0001 27	0 6319 0 0004 27	0 95835 0 0001 27	0 82304 0 0001 27	0 45449 0 0172 27	0 99472 0 0001 27	0 41973 0 0297 27
HH3SQ	0 13184 0 5121 ??	0 19951 0 3438 27	0 14958 0 4565 27	0 28103 0 1556 27	0 98196 0 0001 27	0 98162 0 0001 27	0 99980 0 0001 27	0 50835 0 0068 27	0 90459 0 0001 27	0 72839 0 0031 27	0 31554 0 1089 27	0 9988 0 0001 27	0 .5038 0 0023 27
HH4SQ	0 91370 0 0001 27	0 93587 0 0001 27	0 92083 0 0001 27	0 67074 0 0001 27	0 35276 0 0711 27	0 67631 0 0001 27	0 54029 0 0036 27	0 93985 0 0001 27	0 83664 0 0001 27	0 96503 0 0001 27	0 97373 0 0001 27	0 56160 0 0022 27	0 42199 0 3277 27
HP5Q	0 13980 0 0829 27	0 39414 0 0419 27	0 35660 0 0679 27	0 07033 0 7274 27	0 91923 0 0001 27	0 99975 0 0001 27	0 98116 0 0001 27	0 67999 0 0001 27	0 97459 0 0001 27	0 85753 0 0001 27	0 51028 0 0065 27	0 98618 0 0001 27	0 36007 0 0651 27
SBSQ	0 79499 0 0001 27	0 81983 0 0001 27	0 79596 0 0001 27	0 46673 0 0141 27	0 57298 0 0018 27	0 83732 0 0001 27	0 73142 0 0001 27	0 96455 0 0001 27	0 94602 0 0001 27	0 99988 0 0001 27	0 88731 0 0001 27	0 75019 0 0031 27	0 19653 0 3516 27

	(L	OL(	OL7	OL9	K 11	H2	H3	I 4	I		J	\ I	\ ))
W P C	0 17197 0 0001 7	0 18404 0 0001 27	0 97(03 0 0031 27	0 79341 0 0001 27	0 17837 0 3734 27	0 1 0 0 0043 27	0 17991 0 0507 27	0 11663 0 0001 27	0 724 3 0 0031 27	0 30119 0 0091 7	0 1988 0 0001 27	0 41 2 0 01 9 27	0 5797 0 9015 7
ULIN	0 88 56 0 0091 27	0 70812 0 0001 27	0 89072 0 0001 27	0 61919 0 0006 27	0 41145 0 0110 27	0 7 040 0 0001 27	0 59189 0 0012 27	0 99343 0 0001 27	0 36766 0 0001 27	0 77 39 0 0001 27	0 1 385 0 0001 27	0 61407 0 0007 27	0 36 7 0 1631 7
SOLCA	0 79987 0 0001 27	0 87044 0 0001 27	0 80023 0 0001 27	0 5095 0 0069 27	0 48281 0 0107 27	0 75390 0 0001 27	0 64337 0 0003 7	0 93493 0 0001 27	0 47159 0 0001 27	0 94760 0 0031 27	0 17520 0 0001 27	0 66271 0 0002 27	0 21995 0 045 27
SOLMG	0 78876 0 0001 27	0 92129 0 0001 27	0 79902 0 0001 27	0 48620 0 0101 27	0 53376 0 004 27	0 80101 0 0001 27	0 69288 0 0001 27	0 95757 0 0001 27	0 91461 0 0001 27	0 97730 0 0001 27	0 88359 0 0001 27	0 71194 0 0001 27	-0 21532 0 931 7
SOL	0 67537 0 0001 27	0 69279 0 0001 27	0 68096 0 0001 27	0 48868 0 0097 27	0 27825 0 1599 27	0 51654 0 0058 27	0 41671 0 0306 7	0 74590 0 0001 27	0 63316 0 0004 27	0 72440 0 0001 27	0 7 304 0 0001 27	0 43183 0 0238 27	-0 30149 0 1264 27
OLMA	0 76494 0 0001 27	0 90025 0 0001 27	0 77605 0 0001 27	0 44535 0 0199 27	0 58165 0 0015 27	0 83806 0 0001 27	0 73587 0 0001 27	0 94903 0 0001 27	0 94148 0 0001 27	0 98909 0 0001 27	0 86903 0 0001 27	0 75400 0 0001 27	0 16646 0 4066 27
OIP	0 09634 0 6327 27	0 07031 0 7282 27	0 09832 0 6613 27	0 26882 0 1751 27	0 45101 0 0182 27	0 39724 0 0430 27	0 42649 0 0266 27	0 09549 0 6716 27	0 32281 0 1005 27	0 20717 0 2998 27	0 01089 0 9570 27	0 42168 0 0285 27	0 3 529 0 0610 27

	AIR3SQ	AIR4SQ	SOL1SQ	SOL2SQ	SOL3SQ	SOL4SQ	SOL5SQ	SOL6SQ	SOL7SQ	SOL8SQ	RH1 Q	SH2 Q	P11 Q
U4	0 13344 0 5749 25	0 48921 0 0131 25	0 04715 0 8229 25	0 23284 0 2627 25	0 09863 0 6390 25	0 57820 0 0025 25	0 58882 0 0020 25	0 58304 0 0020 25	0 58875 0 0020 25	0 54083 0 0053 25	0 01799 0 9320 25	0 19688 0 3455 2	0 10507 0 6172 25
UX2	0 51023 0 0109 24	0 14762 0 4912 24	0 45231 0 0265 24	0 19624 0 3581 24	0 33156 0 1135 24	0 50741 0 0114 24	0 43941 0 0317 24	0 41809 0 0420 24	0 43297 0 0346 24	0 56540 0 0040 24	0 43038 0 0358 24	0 23491 0 2694 24	0 32559 0 1235 24
UX3	0 84335 0 0001 24	0 34583 0 0979 24	0 84506 0 0001 24	0 71020 0 0001 24	0 80177 0 0001 24	0 26781 0 2058 24	0 11988 0 5769 24	0 07824 0 7163 24	0 10711 0 6184 24	0 42758 0 0371 24	0 84098 0 0001 24	0 73985 0 0001 24	0 79053 0 0001 24
OX2 3	0 26361 0 2133 24	0 46054 0 0235 24	0 32237 0 1245 24	-0 45253 0 0264 24	0 40223 0 0513 24	0 25741 0 2246 24	0 32488 0 1214 24	0 34172 0 1022 24	0 33014 0 1151 24	0 16935 0 4289 24	0 34032 0 1037 24	0 44143 0 0108 24	0 40518 0 0495 24
MOSM	0 26168 0 2064 25	0 47623 0 0161 25	0 16886 0 4197 25	0 15015 0 4738 25	0 00626 0 9763 25	0 66198 0 0003 25	0 65169 0 0004 25	0 64469 0 0005 25	0 64973 0 0004 25	0 64478 0 0005 25	0 13690 0 5141 25	0 10755 0 6089 25	0 00133 0 9953 25
AIR1	0 91886 0 0001 27	0 72938 0 0001 27	0 96393 0 0001 27	0 98346 0 0001 27	0 99916 0 0001 27	0 02426 0 9044 27	0 18023 0 3683 27	0 23609 0 2358 27	0 19745 0 3235 27	0 25146 0 2058 27	0 97503 0 0001 27	0 99 30 0 0001 27	0 999 3 0 0001 27

	AT 3 0	AT 45?	OTTSC	OL2 0	OL3 0	OL45	OL ?	OL ?	OL7	DH ?	H		? ?
A 12	0 93351	0 17799	0 74721	0 18231	0 7729	0 8 ?43	? 72782	? 68718	0 71 8	0 94914	0 71 ?2	0 41881	0 8
	0 0001	0 3744	0 0001	0 0491	0 0016	0 0001	0 0001	0 0001	0 0031	0 0031	? 3001	0 0 20	? 30 3
	27	27	27	27	27	7	27	?7	27	27	27	27	7
AIB3	0 39996	0 41913	0 99187	0 93692	0 93728	0 40893	0 21413	0 15301	0 1969?	0 60614	0 9450	0 87923	0 33369
	0 0001	0 0146	0 0101	0 0001	0 0001	0 0347	0 2835	0 4112	0 3219	0 0038	0 0001	0 0011	0 0031
	27	27	?7	27	27	7	27	27	?7	?7	27	27	?7
AIB	0 40390	0 99999	0 52419	0 84338	0 733 9	0 66324	0 80193	0 93478	0 81234	0 47522	0 6255	0 30944	0 710 5
	0 0367	0 0001	0 0050	0 0001	0 0001	0 0007	0 0001	0 0001	0 0001	0 0122	0 0023	0 0001	0 0031
	?7	27	27	27	7	27	27	27	27	?7	?7	27	27
SOL1	0 91074	0 2091	1 00000	0 89977	0 97402	0 28947	0 09808	0 03107	0 07060	0 0000	0 91397	0 9 510	0 97163
	0 0001	0 0053	0 0001	0 0001	0 0001	0 1430	0 6622	0 8777	0 7264	0 0071	0 0001	0 0001	0 0001
	27	27	27	27	27	27	27	27	27	27	?7	27	27
SOL2	0 83782	0 83565	0 90819	0 99995	0 97743	0 14709	0 34582	0 39882	0 36222	0 08220	0 92268	0 99866	0 3795
	0 0001	0 0001	0 0001	0 0001	0 0001	0 4641	0 0772	0 0393	0 0633	0 6836	0 0001	0 0001	0 0031
	27	27	27	27	27	27	27	27	27	27	27	27	27
OL3	0 73646	0 69628	0 97542	0 97381	0 99998	0 07143	0 13360	0 19996	0 15095	0 29607	0 98443	0 98 04	0 99995
	0 0001	0 0001	0 0001	0 0001	0 0001	0 7233	0 5065	0 3426	0 4523	0 1327	0 0001	0 0001	0 0031
	27	27	27	27	27	27	27	27	27	27	27	27	27
SOL4	0 3 058	0 73973	0 18998	0 25846	0 03831	0 99464	0 99481	0 98738	0 99287	0 94491	0 14418	0 19806	0 04859
	0 1030	0 0001	0 3451	0 1930	0 8495	0 0001	0 0001	0 0001	0 0001	0 0001	0 4732	0 3220	0 8091
	27	27	27	27	27	27	27	27	27	27	27	7	7
SOL5	0 24035	0 79334	0 10631	0 33824	0 12163	0 98254	0 99983	0 99716	0 99936	0 91427	0 06099	0 27923	0 13198
	0 2272	0 0001	0 5977	0 0844	0 5456	0 0001	0 0001	0 0001	0 0001	0 0001	0 7625	0 1584	0 5121
	27	27	27	27	27	27	27	27	27	27	?7	?7	?7
SOL6	0 18325	0 82734	0 04806	0 39262	0 17940	0 96999	0 99920	0 99986	0 99975	0 88905	0 00259	0 33483	0 19951
	0 3602	0 0001	0 8119	0 0428	0 3706	0 0001	0 0001	0 0001	0 0001	0 0001	0 9898	0 0878	0 3439
	27	27	27	27	27	27	27	27	27	27	27	27	?7
SOL7	0 22292	0 80412	0 08847	0 35505	0 13940	0 97904	1 00000	0 99835	0 99984	0 90687	0 04310	0 29839	0 149 3
	0 2637	0 0001	0 6608	0 0692	0 4880	0 0001	0 0001	0 0001	0 0001	0 0001	0 8310	0 1333	0 4565
	27	27	27	27	27	27	27	27	27	7	27	27	27
SOL8	0 61297	0 47871	0 50000	0 07198	0 29088	0 97369	0 90670	0 88114	0 89916	1 00000	0 41011	0 13369	0 29193
	0 0007	0 0115	0 0079	0 7212	0 1410	0 0001	0 0001	0 0001	0 0001	0 0001	0 0157	0 ?(2	0 15 5
	27	27	27	27	27	27	27	27	27	27	27	27	?7
BH1	0 98298	0 56178	0 99882	0 91988	0 98396	0 24270	0 03966	0 01745	0 02213	0 45740	1 00000	0 94243	0 98135
	0 0001	0 0023	0 0001	0 0001	0 0001	0 2225	0 8443	0 9312	0 9128	0 0164	0 0001	0 0001	0 0031
	27	27	27	27	27	27	27	?7	27	27	27	27	27
BH2	0 84354	0 82980	0 90865	0 99978	0 97961	0 13664	0 33589	0 38912	0 35236	0 09272	0 92670	0 99915	0 991 2
	0 0001	0 0001	0 0001	0 0001	0 0001	0 4968	0 0867	0 0448	0 0715	0 6455	0 0001	0 0001	0 3031
	27	27	27	27	27	27	27	27	27	27	27	27	27

	AI(3	A R4 O	OL1 O	OL2 O	L3 O	L (	OL 5	OL6	SOL7 (	OLHS	H1		I3
RH3	0 9 300 0 0001 27	0 2 07 0 0001 27	0 96670 0 0001 27	0 98148 0 0001 7	0 19951 0 0001 27	0 034 3 0 8629 27	0 16977 0 397 27	0 2 575 0 575 27	0 18702 0 3503 27	0 26173 1073 27	0 97734 0 0001 7	0 931 7 0 0011 27	0 93 13 0 0011 7
RH4	0 15765 0 4327 27	0 96805 0 0001 27	0 290 9 0 1419 27	0 67977 0 0001 27	0 49946 0 0080 27	0 83194 0 0001 27	0 92765 0 0001 27	0 94746 0 0001 27	0 93806 0 0001 27	0 683 9 0 0011 27	0 33330 0 0491 27	0 63192 0 0001 27	0 983 0 3053 7
AT	0 68 63 0 0001 27	0 94152 0 0001 27	0 77913 0 0001 27	0 97422 0 0001 27	0 90016 0 0001 27	0 37597 0 0533 27	0 55713 0 0026 27	0 60363 0 0009 27	0 57161 0 0019 27	0 15489 0 4474 27	0 88 89 0 0001 27	0 3 935 0 0011 7	0 93457 0 0031 27
SA	0 42686 0 0264 27	0 99737 0 0001 27	0 54571 0 0032 27	0 05668 0 0001 27	0 72110 0 0001 27	0 64413 0 0003 27	0 78665 0 0001 27	0 82062 0 0001 27	0 73736 0 0001 7	0 45285 0 0177 27	0 58324 0 0014 27	0 82304 0 0001 27	0 7 839 0 0031 27
W P	0 05390 0 7895 27	0 89350 0 0001 27	0 08220 0 6836 27	0 50895 0 0067 27	0 30576 0 1209 27	0 93015 0 0001 27	0 98550 0 0001 27	0 99159 0 0001 27	0 98833 0 0001 27	0 82199 0 0001 27	0 12743 0 5265 27	0 4 449 0 0172 27	0 31554 0 1089 7
AIR1 Q	0 91188 0 0001 27	0 74113 0 0001 27	0 95917 0 0001 27	0 98645 0 0001 27	0 99830 0 0001 27	0 00694 0 9726 27	0 19774 0 3241 27	0 25289 0 2031 27	0 21441 0 2829 27	0 23465 0 2387 27	0 97104 0 0001 27	0 99472 0 0001 7	0 94985 0 0001 27
AIR2SQ	0 81791 0 0001 27	0 19987 0 3175 27	0 71 21 0 0001 27	0 36162 0 0638 27	0 55894 0 0025 27	0 86388 0 0001 27	0 74293 0 0001 27	0 70350 0 0001 27	0 73107 0 0001 27	0 95594 0 0011 27	0 70049 0 0001 7	0 41874 0 1297 27	0 5 033 0 00 9 27
AIR3 Q	1 00000 0 0000 27	0 40025 0 0386 27	0 99074 0 0001 27	0 83218 0 0001 27	0 93424 0 0001 27	0 41677 0 0306 27	0 22253 0 2646 27	0 16651 0 4065 27	0 20540 0 3040 27	0 61297 0 0007 27	0 98354 0 0001 27	0 86496 0 0001 27	0 93051 0 0011 27
AIR4 Q	0 4002 0 0386 27	1 00000 0 0000 27	0 52099 0 0053 27	0 84123 0 0001 27	0 70076 0 0001 27	0 66621 0 0001 27	0 80436 0 0001 27	0 83697 0 0001 27	0 81465 0 0001 27	0 47871 0 0115 27	0 55926 0 0024 27	0 80609 0 0001 27	0 70805 0 0001 27
SOL1 Q	0 99074 0 0001 27	0 52099 0 0053 27	1 00000 0 0000 27	0 89977 0 0001 27	0 97402 0 0001 27	0 28947 0 1430 27	-0 08808 0 6622 27	0 03107 0 8777 27	0 07060 0 7264 27	0 50000 0 0079 27	0 99897 0 0001 27	0 92510 0 0001 27	0 97164 0 0011 27
SOL2SQ	0 81210 0 0001 27	0 84123 0 0001 27	0 89977 0 0001 27	1 00000 0 0000 27	0 97521 0 0001 27	0 15722 0 4335 27	0 35542 0 0689 27	0 40820 0 0345 27	0 37175 0 0562 27	0 07198 0 7212 27	0 91868 0 0001 27	0 99808 0 0001 27	0 97743 0 0001 27
SOL3SQ	0 93424 0 0001 27	0 70076 0 0001 27	0 97402 0 0001 27	0 97521 0 0001 27	1 00000 0 0000 27	0 06518 0 7467 27	0 13980 0 4868 27	0 19610 0 3269 27	0 15714 0 4338 27	0 29088 0 1410 27	0 98331 0 0001 27	0 98706 0 0001 27	0 99935 0 0031 27
SOL4SQ	0 41677 0 0306 27	0 66621 0 0001 27	0 28947 0 1430 27	0 15722 0 4335 27	0 06518 0 7467 27	1 00000 0 0000 27	0 97896 0 0001 27	0 96572 0 0001 27	0 97523 0 0001 27	0 97369 0 0001 27	0 24565 0 2168 27	0 09 68 0 6350 27	0 0 491 0 7856 27

	ATR3 Q	ATB4SQ	OL1SL	SOL2SQ	OL3 Q	OL4	SOL5 Q	SOL6 Q	OL7	OL8 Q	[illegible]	[illegible]	[illegible]
SOL Q	0 22253 0 2646 7	0 80416 0 0001 27	0 08809 0 6622 27	0 35542 0 0689 27	0 13980 0 4869 27	0 97896 0 0001 27	1 00000 0 0000 27	0 91837 0 0001 27	0 99985 0 0001 27	0 90670 0 0001 27	0 04 70 0 815 7	0 1677 0 1328 27	0 14971 0 15 1 7
SOL6SQ	0 14651 0 4065 27	0 83697 0 0001 27	0 01107 0 9777 27	0 40820 0 0345 27	0 13610 0 3269 27	0 96572 0 0001 27	0 99937 0 0001 27	1 00000 0 0000 27	0 99922 0 0001 27	0 88114 0 0001 27	0 01441 0 9431 27	35081 0 0728 27	0 3617 0 1022 7
SOL7SQ	0 20540 0 3040 27	0 81465 0 0001 27	0 07060 0 7264 27	0 37175 0 0562 27	0 15714 0 4339 27	0 97 23 0 0001 27	0 99985 0 0001 27	0 91922 0 0001 27	1 00000 0 0000 27	0 89916 0 0001 27	0 02517 0 9098 27	0 31347 0 1113 27	0 157 3 1 1033 27
OL8 Q	0 61297 0 0007 27	0 47871 0 0115 27	0 50000 0 0079 27	0 07198 0 7212 27	0 23088 0 1410 27	0 97368 0 0001 27	0 90670 0 0001 27	0 88114 0 0001 27	0 89916 0 0001 27	1 00000 0 0000 27	0 46011 0 0157 27	0 13369 0 5062 27	0 28103 0 1555 27
BB1SQ	0 98354 0 0001 27	0 55926 0 0024 27	0 99897 0 0001 27	0 91868 0 0001 27	0 99311 0 0001 27	0 74565 0 2168 27	0 04270 0 8325 27	0 01441 0 9431 27	0 02517 0 9008 27	0 46011 0 0157 27	1 00000 0 0009 27	0 94141 0 0001 27	0 91139 0 0001 27
BB2SQ	0 86496 0 0001 27	0 90609 0 0001 27	0 92510 0 0001 27	0 99808 0 0001 27	0 98705 0 0001 27	0 09568 0 6350 27	0 29677 0 1328 27	0 35081 0 0728 27	0 31347 0 1113 27	0 13369 0 5062 27	0 94141 0 0001 27	1 00000 0 0000 27	0 11865 0 0001 27
BB3SQ	0 93053 0 0001 27	0 70806 0 0001 27	0 97164 0 0001 27	0 97744 0 0001 27	0 99995 0 0001 27	0 05491 0 7856 27	0 14998 0 4553 27	0 20617 0 3022 27	0 16729 0 4043 27	0 28103 0 1556 27	0 98138 0 0001 27	0 98866 0 0001 27	1 00000 0 0000 27
BB4SQ	0 17488 0 3830 27	0 97228 0 0001 27	0 30696 0 1194 27	0 69149 0 0001 27	0 51452 0 0060 27	0 82212 0 0001 27	0 92099 0 0001 27	0 94173 0 0001 27	0 92768 0 0001 27	0 67074 0 0001 27	0 34991 0 0736 27	0 64536 0 0003 27	0 52311 0 0051 7
BF Q	0 93126 0 0001 27	0 88213 0 0001 27	0 89905 0 0001 27	1 00000 0 0001 27	0 97485 0 0001 27	0 15886 0 4287 27	0 35697 0 0676 27	0 40971 0 0338 27	0 37329 0 0551 27	0 07033 0 7274 27	0 91802 0 0001 27	0 99797 0 0001 27	0 97709 0 0001 27
SBSQ	0 41268 0 0324 27	0 99991 0 0001 27	0 53255 0 0043 27	0 84451 0 0001 27	0 71039 0 0001 27	0 63600 0 0002 27	0 79620 0 0001 27	0 82944 0 0001 27	0 80669 0 0001 27	0 46673 0 0141 27	0 7048 0 0919 27	0 81406 0 0001 27	0 71760 0 0001 27
WSP Q	0 00 41 0 9786 27	0 91423 0 0001 27	0 13043 0 5167 27	0 55000 0 0030 27	0 35158 0 0721 27	0 91125 0 0001 27	0 97612 0 0001 27	0 98693 0 0001 27	0 97978 0 0001 27	0 79341 0 0001 27	0 17538 0 3816 27	0 4971 0 0083 27	0 36119 0 0642 27
SOLIR	0 23767 0 2326 27	0 98227 0 0001 27	0 36693 0 0597 27	0 73458 0 0001 27	0 56729 0 0020 27	0 78093 0 0001 27	0 89090 0 0001 27	0 91497 0 0001 27	0 89860 0 0001 27	0 61919 0 0006 27	0 40869 0 0343 27	0 69138 0 0001 27	0 57569 0 0017 27
SOLCA	0 32393 0 0993 27	0 94980 0 0001 27	0 44246 0 0208 27	0 76583 0 0001 27	0 62180 0 0005 27	0 67852 0 0001 27	0 80043 0 0001 27	0 82853 0 0001 27	0 80934 0 0001 27	0 50855 0 0068 27	0 48031 0 0112 27	0 72931 0 0001 27	0 62918 0 0004 27

	AIR3 1	AIR4 O	OL1SO	OL2 Q	SIL3	OLVS	SOL)	SOLESC	JL7 O	O OS	R11	I II	3 J
UIM	0 37337 0 0 51 27	0 17881 0 0001 27	0 49290 0 0090 27	0 81255 0 0001 27	0 67158 0 0001 27	0 66707 0 0001 27	0 79925 0 0001 27	0 83027 0 0001 27	0 90904 0 0301 27	0 48620 0 0101 27	0 5307 0 0044 27	0 77712 0 0001 27	0 77817 0 0001 27
SOLK	0 14629 0 4665 27	0 72936 0 0001 27	0 24434 0 2193 27	0 52764 0 0047 27	0 11771 0 0399 27	0 60442 0 0009 27	0 68104 0 0001 27	0 69741 0 0001 27	0 68634 0 0001 27	0 48869 0 0197 27	0 27616 0 1637 27	0 47388 0 0188 27	0 49421 0 1365 27
SOLNA	0 42481 0 0272 27	0 98858 0 0001 27	0 54216 0 0035 27	0 84881 0 0001 27	0 71543 0 0001 27	0 63490 0 0004 27	0 77630 0 0001 27	0 41002 0 0001 27	0 78692 0 0001 27	0 44535 0 0199 27	0 57922 0 0016 27	0 81 69 0 0031 27	0 7274 0 0001 27
SOLP	0 45625 0 0168 27	0 19520 0 3292 27	0 45389 0 0174 27	0 39730 0 0459 27	0 43115 0 0247 27	0 17769 0 3753 27	0 08815 0 6620 27	0 06243 0 7570 27	0 08028 0 6906 27	0 26892 0 1751 27	0 45122 0 0182 27	0 40153 0 0379 27	0 4 9 9 0 0351 27

	3HHSQ	RPSQ	SBSQ	WSP_Q	SOLTH	SO CA	SOLH	SOLK	SOLNA	SOLP
OX	0 54949 0 0045 25	0 23378 0 2607 25	0 48490 0 0140 25	0 57707 0 0025 25	0 54322 0 0050 25	0 49392 0 0121 25	0 53858 0 0055 25	0 34541 0 0908 25	0 52915 0 0065 25	0 27759 0 1791 25
OX2	0 26941 0 2030 24	0 19521 0 3607 24	0 14014 0 5137 24	0 35225 0 0914 24	0 21247 0 3189 24	0 21790 0 3064 24	0 20071 0 3470 24	0 20900 0 3294 24	0 14967 0 4852 24	0 14819 0 4895 24
OX3	0 17387 0 4165 24	0 70937 0 0001 24	0 35559 0 0881 24	0 04050 0 8510 24	0 24754 0 2435 24	0 31422 0 1348 24	0 35244 0 0912 24	0 10329 0 6310 24	0 39355 0 0571 24	0 43908 0 0318 24
OX2 3	0 42432 0 0388 24	0 45280 0 0263 24	0 46204 0 0230 24	0 38476 0 0634 24	0 43513 0 0336 24	0 50118 0 0126 24	0 51899 0 0094 24	0 29944 0 1552 24	0 50599 0 0116 24	0 54536 0 0058 24
MOJN	0 56601 0 0032 25	0 15127 0 4704 25	0 47019 0 0177 25	0 61532 0 0011 25	0 56678 0 0033 25	0 57733 0 0025 25	0 54420 0 0049 25	0 51043 0 0091 25	0 50246 0 0105 25	0 03528 0 8670 25
AIR1	0 54920 0 0030 27	0 98316 0 0001 27	0 73862 0 0001 27	0 38962 0 0445 27	0 60038 0 0009 27	0 65079 0 0002 27	0 70019 0 0001 27	0 42326 0 0278 27	0 74280 0 0001 27	0 42465 0 0273 27
AIR2	0 40314 0 0371 27	0 38078 0 0501 27	0 16458 0 4120 27	0 56185 0 0023 27	0 34179 0 0810 27	0 22943 0 2497 27	0 19394 0 3323 27	0 28619 0 1478 27	0 14468 0 4715 27	0 37129 0 0565 27
AIR3	0 18335 0 3600 27	0 33602 0 0001 27	0 42051 0 0290 27	0 00320 0 9874 27	0 24600 0 2161 27	0 33162 0 0911 27	0 38115 0 0498 27	0 15259 0 4474 27	0 43248 0 0243 27	0 45636 0 0167 27
AIR4	0 97134 0 0001 27	0 84427 0 0001 27	0 99995 0 0001 27	0 91261 0 0001 27	0 48158 0 0001 27	0 94954 0 0001 27	0 97872 0 0001 27	0 72872 0 0001 27	0 98870 0 0001 27	0 19684 0 3251 27

	RH4SQ	PP O	SP)	KSPSO	JLT I	OLCA	OLM	OLK	OLNA	OI
SOL1	0 30696	0 89905	0 53 55	0 13043	0 1 693	0 44246	0 49280	0 24414	0 54 16	0 45389
	0 1194	0 0001	0 0043	0 5167	0 0 77	0 0208	0 0090	0 2193	0 0035	0 0174
	27	27	27	27	27	27	27	27	27	27
SOL2	0 68405	0 99993	0 84304	0 54141	0 72764	0 75999	0 80691	0 52270	0 84356	0 38975
	0 0001	0 0001	0 0001	0 0036	0 0001	0 0001	0 0001	0 0052	0 0001	0 0445
	27	27	27	27	27	27	27	27	27	27
SOL3	0 0914	0 97341	0 70599	0 34571	0 56215	0 61721	0 66711	0 39377	0 71114	0 43208
	0 0367	0 0001	0 0001	0 0773	0 0021	0 0006	0 0001	0 0421	0 0001	0 0244
	27	27	27	27	27	27	27	27	27	27
SOL4	0 87656	0 26006	0 73050	0 94394	0 84079	0 74388	0 73757	0 64646	0 70990	0 13326
	0 0001	0 1902	0 0001	0 0001	0 0001	0 0001	0 0001	0 0003	0 0001	0 5076
	27	27	27	27	27	27	27	27	27	27
SOL5	0 91370	0 33980	0 78499	0 97197	0 98256	0 79087	0 78876	0 67537	0 76494	0 09634
	0 0001	0 0829	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 6327
	27	27	27	27	27	27	27	27	27	27
SOL6	0 93587	0 39414	0 81983	0 98404	0 90812	0 82044	0 82124	0 69279	0 80025	0 07011
	0 0001	0 0419	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 7282
	27	27	27	27	27	27	27	27	27	27
SOL7	0 92083	0 35660	0 79596	0 97603	0 89072	0 80023	0 79902	0 68096	0 77605	0 08832
	0 0001	0 0679	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 6613
	27	27	27	27	27	27	27	?7	27	27
SOL8	0 67074	0 07033	0 46673	0 79341	0 61919	0 50855	0 48620	0 48069	0 44535	0 26882
	0 0001	0 7274	0 0141	0 0001	0 0006	0 0068	0 0101	0 0097	0 0199	0 1751
	27	27	27	27	27	27	27	27	27	27
BB1	0 35276	0 91973	0 57298	0 17837	0 41145	0 48281	0 53326	0 27826	0 58165	0 45101
	0 0711	0 0001	0 0018	0 3734	0 0330	0 0107	0 004?	0 1599	0 0015	0 0182
	27	27	27	27	27	27	27	27	27	27
BB2	0 67631	0 99975	0 83732	0 53250	0 72040	0 75390	0 80101	0 51654	0 83806	0 39224
	0 0001	0 0001	0 0001	0 0043	0 0001	0 0001	0 0001	0 0058	0 0001	0 0430
	27	27	27	27	27	27	27	27	27	27
BB3	0 54029	0 98116	0 73142	0 37981	0 59189	0 64337	0 69289	0 41671	0 73582	-0 42640
	0 0036	0 0001	0 0001	0 0507	0 0012	0 0003	0 0001	0 0306	0 0001	0 0266
	27	27	27	27	27	27	27	27	27	27
BB4	0 99985	0 67999	0 96455	0 98663	0 99383	0 93483	0 95257	0 74590	0 94903	0 08549
	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 6716
	27	27	27	27	27	27	27	27	27	27
HP	0 83664	0 97459	0 94602	-0 72423	0 96766	0 87358	0 91481	0 63316	0 94148	0 32281
	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0004	0 0001	0 1005
	27	27	27	27	27	27	27	27	27	27

	14 2	PPS3	S9S0	W I O	[illegible]	OL A	OLN	OLK	OL P	SOLI
SB	0 36 03	0 45753	0 99989	0 90199	0 97681	0 94761	0 97780	0 72440	0 8909	0 20717
	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0101	0 0001	0 2999
	27	27	27	27	27	27	27	27	7	27
WSP	0 97373	0 1029	0 98731	0 99882	0 95385	0 87620	0 88351	0 72304	0 86903	0 01093
	0 0001	0 0065	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 9 70
	27	27	27	27	7	27	27	27	27	27
AIR1SQ	0 56360	0 98618	0 75019	0 40552	0 61407	0 66273	0 71194	0 43385	0 75400	0 42160
	0 0022	0 0001	0 0001	0 0359	0 0007	0 0002	0 0001	0 0 38	0 0001	0 0295
	27	27	27	27	27	27	7	27	27	27
AIR2SQ	0 42344	0 36007	0 18653	0 57976	0 362 7	0 24996	0 21332	0 30149	0 16646	0 36528
	0 0277	0 0651	0 3516	0 001	0 0631	0 2086	0 908	0 1264	0 4066	0 0610
	27	27	27	27	27	27	27	27	27	27
AIR3SQ	0 17498	0 83126	0 41268	0 00541	0 3767	0 32193	0 37337	0 14629	0 42481	0 45625
	0 3830	0 0001	0 0324	0 9796	0 2326	0 0993	0 0551	0 4665	0 0272	0 0168
	27	27	27	27	27	27	27	27	27	27
AIR4SQ	0 97 28	0 94213	0 99991	0 91423	0 98227	0 94980	0 97881	0 72936	0 98858	0 19520
	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 3292
	27	27	27	27	27	27	27	27	27	27
SOL1SQ	0 30696	0 89903	0 53255	0 13043	0 36693	0 44246	0 49280	0 24434	0 54216	0 45389
	0 1194	0 0001	0 0043	0 5167	0 0597	0 0208	0 0090	0 2193	0 0035	0 0174
	27	27	27	27	27	27	27	27	27	27
SOL2SQ	0 69149	1 00000	0 88851	0 55000	0 73458	0 76583	0 81255	0 52764	0 84881	0 38730
	0 0001	0 0001	0 0001	0 0030	0 0001	0 0001	0 0001	0 0047	0 0001	0 0459
	27	27	27	27	27	27	27	27	27	27
SOL3SQ	0 51452	0 97485	0 71039	0 35158	0 56729	0 62180	0 67158	0 39773	0 71543	0 43115
	0 0060	0 0001	0 0001	0 0721	0 0020	0 0005	0 0001	0 0199	0 0001	0 0247
	27	27	27	27	27	27	27	27	27	27
SOL4SQ	0 82212	0 15886	0 65600	0 91125	0 79093	0 67852	0 66707	0 60442	0 63490	0 17768
	0 0001	0 4287	0 0002	0 0001	0 0001	0 0001	0 0001	0 0009	0 0004	0 3753
	27	27	27	27	27	27	27	27	27	27
SOL5SQ	0 92099	0 35697	0 79620	0 97612	0 89090	0 80043	0 79925	0 68108	0 77630	0 08815
	0 0001	0 0676	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 6620
	27	27	27	27	27	27	27	27	27	27
SOL6SQ	0 94173	0 40971	0 82944	0 98693	0 91497	0 82853	0 83022	0 69741	0 81002	0 06243
	0 0001	0 0338	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 7570
	27	27	27	27	27	27	27	27	27	27
SOL7SQ	0 92768	0 37329	0 80669	0 97978	0 89860	0 80934	0 80904	0 68634	0 78692	0 08028
	0 0001	0 0551	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 0001	0 6906
	27	27	27	27	27	27	27	27	27	27

	914 Q	DPSQ	CDS1	W P Q	OLIM	OLCA	OLM	OLK	OLMA	SOL
OLBSQ	0 67074 0 0001 27	0 07033 0 7274 27	0 46673 0 3141 27	0 79341 0 0001 27	0 61919 0 0006 27	0 50853 0 0068 27	0 48620 0 0101 27	0 41868 0 0197 27	0 44535 0 0199 27	0 26892 0 1751 27
BRCSQ	0 34991 0 0736 27	0 91802 0 0001 27	0 57048 0 0019 27	0 17538 0 3916 7	0 40869 0 0343 27	0 48011 0 0112 27	0 53076 0 0044 27	0 27616 0 1632 27	0 57922 0 0016 27	0 45122 0 0182 27
BR Z Q	0 64536 0 0003 27	0 99797 0 0001 27	0 81406 0 0001 27	0 43715 0 0083 27	0 69139 0 0001 27	0 72931 0 0001 27	0 77712 0 0001 27	0 43388 0 0088 27	0 41569 0 0001 27	0 40153 0 0379 27
BBCSQ	0 52331 0 0051 27	0 97709 0 0001 27	0 71760 0 0001 27	0 36119 0 0642 27	0 57569 0 0017 27	0 62918 0 0004 27	0 67487 0 0001 27	0 49421 0 0165 27	0 72242 0 0001 27	0 42958 0 0253 27
DD4SQ	1 00000 0 0000 27	0 69269 0 0001 27	0 96901 0 0001 27	0 98363 0 0001 27	0 99471 0 0001 27	0 91781 0 0001 27	0 95637 0 0001 27	0 74630 0 0001 27	0 95375 0 0001 27	0 09331 0 6434 27
BF Q	0 69269 0 0001 27	1 00000 0 0000 27	0 84939 0 0001 27	0 55138 0 0029 27	0 73570 0 0001 27	0 76676 0 0001 27	-0 81345 0 0001 27	0 52151 0 0046 27	0 84965 0 0001 27	0 38690 0 0462 27
SBSQ	0 96901 0 0001 27	0 84939 0 0001 27	1 00000 0 0000 27	0 90863 0 0001 27	0 97987 0 0001 27	0 94887 0 0001 27	0 97845 0 0001 27	0 72711 0 0001 27	0 98893 0 0001 27	0 20079 0 3153 27
SP Q	0 98363 0 0001 27	0 55138 0 0029 27	0 90863 0 0001 27	1 00000 0 0000 27	0 96676 0 0001 27	0 89313 0 0001 27	0 90299 0 0001 27	0 73119 0 0001 27	0 89091 0 0001 27	0 01126 0 9555 27
SOLIM	0 99471 0 0001 27	0 73570 0 0001 27	0 97987 0 0001 27	0 96676 0 0001 27	1 00000 0 0000 27	0 94397 0 0001 27	0 96484 0 0001 27	0 74189 0 0001 27	0 96741 0 0001 27	0 11658 0 5625 27
SOLCA	0 93781 0 0001 27	0 76676 0 0001 27	0 94887 0 0001 27	0 89319 0 0001 7	0 94397 0 0001 27	1 00000 0 0000 27	0 98192 0 0001 27	0 80096 0 0001 27	0 95996 0 0001 27	0 27985 0 1574 27
OLMG	0 95637 0 0001 27	0 81345 0 0001 27	0 97845 0 0001 27	0 90299 0 0001 27	0 96484 0 0001 27	0 98192 0 0001 27	1 00000 0 0000 27	0 76010 0 0001 27	0 98468 0 0001 27	0 27913 0 1505 27
OLK	0 74630 0 0001 27	0 52851 0 0046 27	0 72711 0 0001 27	0 73119 0 0001 27	0 74189 0 0001 27	0 80096 0 0001 27	0 76010 0 0001 27	1 00000 0 0000 27	0 74604 0 0001 27	0 09308 0 6442 27
SOLMA	0 95175 0 0001 27	0 94965 0 0001 27	0 98893 0 0001 27	0 89091 0 0001 27	0 96741 0 0001 27	0 95996 0 0001 27	0 98468 0 0001 27	0 74604 0 0001 27	1 00000 0 0000 27	0 25514 0 1990 27
L	0 01311 0 6438 27	0 18610 0 0462 27	0 20079 0 3153 27	0 01126 0 9555 27	0 11659 0 5625 27	0 27985 0 1574 27	0 7311 0 1505 27	0 09309 0 644 27	0 25514 0 1990 27	1 10000 0 0000 27

Appendix E Oxalate content of cassava leaves from plants grown in irrigated plots

Site	Oxalate ($cmol\ kg^{-1}$ dry weight)		
	Total	Insoluble	Soluble*
Molokai	32 6	25 1	7 5
'	19 3	13 3	6 0
"	28 9	21 2	7 4
'	21 6	19 1	2 5
Waipio	34 3	38 4	-
"	29 8	32 0	-
'	23 3	24 7	1 9
"	24 4	22 5	1 9
Iole	35 9	32 8	2 1
	18 9	13 2	5 7
"	19 9	17 2	2 7
"	23 1	21 0	2 1
"	21 8	18 5	3 3
"	18 2	12 6	5 6
Kukaiau	25 9	28 0	-
"	17 8	14 3	3 5
'	26 1	20 0	6 1
"	15 6	26 4	-
"	18 3	19 7	-
'	16 1	23 0	-

*Calculated from the difference between total and insoluble oxalate

Appendix F   Correlation matrix of various plant compositions and soil and climatic factors in taro leaves from three experimental sites

	OX2	OX3	OX2_3	C_A	TOTALN	CA	MG	K	NA	SC	P	S	NO3
OX2	1 00000 0 0000 39	0 34731 0 0303 39	0 42104 0 0076 39	0 19704 0 2292 39	0 09385 0 5699 39	0 78908 0 0001 39	0 28956 0 0738 39	0 69308 0 0001 39	-0 56753 0 0002 39	0 25365 0 1192 39	0 75798 0 0001 39	0 27868 0 0858 39	0 14715 0 3713 39
OX3	0 34731 0 0303 39	1 00000 0 0000 39	0 70435 0 0001 39	0 38540 0 0154 39	0 10987 0 5055 39	0 43819 0 0053 39	0 12856 0 4354 39	0 18969 0 2474 39	0 35255 0 0277 39	0 40520 0 0105 39	0 18937 0 2482 39	0 17983 0 2733 39	0 07497 0 6505 39
OX2_3	0 42104 0 0076 39	0 70435 0 0001 39	1 00000 0 0000 39	0 22362 0 1712 39	0 17731 0 2802 39	0 17272 0 2930 39	0 34354 0 0323 39	0 34117 0 0335 39	0 08861 0 5917 39	0 19992 0 2224 39	0 39061 0 0139 39	0 03701 0 8230 39	-0 18382 0 2626 39
C_A	0 19704 0 2292 39	0 38540 0 0154 39	0 22362 0 1712 39	1 00000 0 0000 40	0 19320 0 2323 40	0 53635 0 0004 40	0 63420 0 0001 40	0 16518 0 3084 40	0 45080 0 0035 40	0 96785 0 0001 40	0 01419 0 9307 40	0 15206 0 3489 40	-0 03377 0 8361 40
TOTALN	0 09385 0 5699 39	0 10987 0 5055 39	0 17731 0 2802 39	0 19320 0 2323 40	1 00000 0 0000 40	0 01608 0 9216 40	0 16829 0 2993 40	0 33655 0 0337 40	0 20624 0 2017 40	0 06914 0 6716 40	0 01902 0 9121 40	0 00382 0 9813 40	0 17915 0 2687 40
CA	0 78808 0 0001 39	0 43819 0 0053 39	0 17272 0 2930 39	0 53635 0 0004 40	0 01608 0 9216 40	1 00000 0 0000 40	0 04170 0 7983 40	0 66308 0 0001 40	0 62699 0 0001 40	0 61434 0 0001 40	0 68466 0 0001 40	0 51313 0 0007 40	0 09641 0 5539 40
MG	0 28956 0 0738 39	0 12856 0 4354 39	0 34354 0 0323 39	0 63420 0 0001 40	0 16829 0 2993 40	0 04170 0 7983 40	1 00000 0 0000 40	0 30344 0 0570 40	0 12293 0 4498 40	0 67199 0 0001 40	0 45701 0 0030 40	0 16383 0 3124 40	0 15108 0 3521 40
K	0 69308 0 0001 39	0 18969 0 2474 39	0 34117 0 0335 39	0 16518 0 3084 40	0 33655 0 0337 40	0 66108 0 0001 40	0 30344 0 0570 40	1 00000 0 0000 40	0 23197 0 1499 40	0 04108 0 8013 40	0 73651 0 0001 40	0 51634 0 0007 40	0 0093 0 2117 [illegible]

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	OX2	OX3	OX2_3	C_A	TOTALN	CA	M	K	NA	SC	P		NO
NA	0 56753	0 35255	0 08861	0 45080	0 20624	0 62699	0 12293	0 23197	1 00000	0 43290	0 40386	0 02940	0 32426
	0 0002	0 0277	0 5917	0 0035	0 2017	0 0001	0 4498	0 1490	0 0000	0 0053	0 0098	0 8571	0 0412
	39	39	39	40	40	40	40	40	42	40	40	40	40
SC	0 25365	0 40520	0 19992	0 96785	0 06914	0 61434	0 67199	0 04108	0 43290	1 00000	0 03453	0 32319	0 07021
	0 1192	0 0105	0 2224	0 0001	0 6716	0 0001	0 0001	0 8013	0 0053	0 0000	0 8325	0 0419	0 6669
	39	39	39	40	40	40	40	40	40	40	40	40	40
P	0 75798	-0 18937	0 39061	0 01419	0 01802	-0 68466	0 45701	0 73651	0 40386	0 03453	1 00000	0 42328	0 02946
	0 0001	0 2482	0 0139	0 9307	0 9121	0 0001	0 0030	0 0001	0 0098	0 8325	0 0000	0 0065	0 8569
	39	39	39	40	40	40	40	40	40	40	40	40	40
S	0 27868	0 17983	0 03701	0 15206	0 00382	0 51313	0 16383	-0 51634	0 02940	0 32319	0 42328	1 00000	-0 37119
	0 0858	0 2733	0 8230	0 3489	0 9813	0 0007	0 3124	0 0007	0 8571	0 0419	0 0065	0 0000	0 0184
	39	39	39	40	40	40	40	40	40	40	40	40	40
NO3	0 14715	0 07487	0 18382	0 03377	0 17915	0 09643	-0 15108	0 20098	0 32426	0 07021	0 02946	0 37118	1 00000
	0 3713	0 6505	0 2626	0 8361	0 2687	0 5539	0 3521	0 2137	0 0412	0 6668	0 8568	0 0184	0 0000
	39	39	39	40	40	40	40	40	40	40	40	40	40
CL	0 26532	0 12287	0 08200	0 07487	-0 50879	0 38444	0 15465	0 54791	0 06256	0 17465	0 25245	0 71111	0 28944
	0 1026	0 4562	0 6197	0 6461	0 0008	0 0143	0 3407	0 0003	0 7014	0 2811	0 1161	0 0001	0 0701
	39	39	39	40	40	40	40	40	40	40	40	40	40
SA	0 23888	0 10590	0 07839	0 06682	0 48035	0 34192	0 18838	0 48221	-0 04361	0 18630	-0 19239	0 68808	0 14662
	0 1430	0 5211	0 6352	0 6821	0 0017	0 0308	0 2444	0 0016	0 7893	0 2497	0 2343	0 0001	0 3666
	39	39	39	40	40	40	40	40	40	40	40	40	40
AIRMAX	0 59825	-0 29020	0 17216	0 15882	0 62805	-0 52379	0 47734	0 29849	0 52391	-0 09614	0 64363	0 10528	0 16145
	0 0001	0 0731	0 2946	0 3277	0 0001	0 0005	0 0018	0 0614	0 0004	0 5551	0 0001	0 5179	0 3196
	39	39	39	40	40	40	40	40	42	40	40	40	40
AIRMIN	0 27176	0 27336	-0 05869	-0 25199	0 82693	0 26240	0 24726	0 04530	0 44164	0 14683	0 33282	0 00747	-0 15800
	0 0942	0 0922	0 7227	0 1167	0 0001	0 1019	0 1240	0 7813	0 0034	0 3659	0 0359	0 9635	0 3302
	39	39	39	40	40	40	40	40	42	40	40	40	40
AIRAVE	0 51682	-0 29260	0 10820	-0 19070	0 70339	-0 45887	0 42060	0 20323	-0 51193	0 11373	0 56695	-0 07869	-0 16450
	0 0008	0 0707	0 5121	0 2385	0 0001	0 0029	0 0069	0 2085	0 0005	0 4847	0 0001	0 6293	0 3105
	39	39	39	40	40	40	40	40	42	40	40	40	40
RHMAX	0 07867	0 23960	0 17221	0 27684	0 85443	0 10704	-0 10907	0 21514	0 36476	0 15949	0 14626	-0 04265	0 14230
	0 6340	0 1418	0 2945	0 0837	0 0001	0 5109	0 5029	0 1825	0 0175	0 3256	0 3678	0 7938	0 3811
	39	39	39	40	40	40	40	40	42	40	40	40	40
RHMIN	0 69774	0 27589	0 26131	0 10474	0 49064	0 60189	-0 54484	0 43086	0 52172	0 06597	-0 73490	0 14140	0 15074
	0 0001	0 0891	0 1081	0 5201	0 0013	0 0001	0 0003	0 0055	0 0004	0 6859	0 0001	0 3841	0 3532
	39	39	39	40	40	40	40	40	42	40	40	40	40
RHAVE	0 56263	0 29201	0 14345	0 17377	0 66401	0 49545	-0 45261	0 25573	0 51973	0 10441	0 61021	0 09340	0 16324
	0 0002	0 0713	0 3836	0 2836	0 0001	0 0012	0 0034	0 1112	0 0004	0 5214	0 0001	0 5665	0 3142
	39	39	39	40	40	40	40	40	42	40	40	40	40

	OX2	OX3	OX2_3	C_A	TOTALN	CA	M	K	NA	C	P		NO3
ISMAX	0 07041	0 23786	0 17677	0 27753	0 85451	0 10037	0 10312	0 22201	0 36113	0 15983	0 13822	0 04471	0 14146
	0 6702	0 1448	0 2817	0 0829	0 0001	0 5377	0 5266	0 1686	0 0188	0 3246	0 3950	0 7841	0 3839
	39	39	39	40	40	40	40	40	42	40	40	40	40
TSMIN	0 30314	-0 27748	0 03892	-0 24626	0 81742	0 28759	0 26958	0 01585	0 45260	0 14391	0 36297	0 01604	0 1 979
	0 0607	0 0872	0 8140	0 1256	0 0001	0 0720	0 0925	0 9227	0 0026	0 3760	0 0213	0 9210	0 3247
	39	39	39	40	40	40	40	40	42	40	40	40	40
TSAVE	0 17239	0 25771	0 11877	0 26690	0 84740	0 18255	0 17633	0 13501	0 40401	0 15456	0 23706	0 01885	-0 15089
	0 2940	0 1132	0 4714	0 0959	0 0001	0 2596	0 2764	0 4062	0 0080	0 3410	0 1408	0 9081	0 3527
	39	39	39	40	40	40	40	40	42	40	40	40	40
SSMAX	0 71984	0 26977	0 28397	-0 08879	0 44829	0 61880	0 55925	0 46432	-0 51660	0 05701	0 75441	-0 15033	0 14652
	0 0001	0 0967	0 0798	0 5859	0 0037	0 0001	0 0002	0 0025	0 0005	0 7268	0 0001	0 3545	0 3670
	39	39	39	40	40	40	40	40	42	40	40	40	40
SSMIN	0 70116	-0 27505	0 26472	-0 10240	0 48449	0 60452	0 54709	0 43591	0 52109	0 06466	0 73795	0 14275	0 15015
	0 0001	0 0901	0 1034	0 5295	0 0015	0 0001	0 0003	0 0049	0 0004	0 6918	0 0001	0 3796	0 3551
	39	39	39	40	40	40	40	40	42	40	40	40	40
SSAVE	0 71126	-0 27233	0 27500	-0 09523	0 46589	0 61227	0 55370	0 45108	0 51889	0 06063	0 74689	0 14680	0 14828
	0 0001	0 0935	0 0902	0 5589	0 0025	0 0001	0 0002	0 0035	0 0004	0 7101	0 0001	0 3660	0 3612
	39	39	39	40	40	40	40	40	42	40	40	40	40
WF	0 72193	0 26910	0 28620	0 08716	0 44394	0 62038	-0 56059	-0 46759	0 51597	0 05610	-0 75622	0 15120	0 14607
	0 0001	0 0976	0 0773	0 5928	0 0041	0 0001	0 0002	0 0024	0 0005	0 7310	0 0001	0 3517	0 3685
	39	39	39	40	40	40	40	40	42	40	40	40	40
RAD	0 62273	0 28813	0 19270	-0 14745	0 60004	-0 54319	0 49420	0 32904	0 52558	0 08982	0 66642	0 11371	0 15971
	0 0001	0 0753	0 2399	0 3639	0 0001	0 0003	0 0012	0 0382	0 0004	0 5815	0 0001	0 4848	0 3249
	39	39	39	40	40	40	40	40	42	40	40	40	40
WIND	0 54118	0 29251	-0 12673	0 18199	0 68332	0 47834	0 43765	-0 23084	0 51638	0 10894	0 59000	0 08644	0 16397
	0 0004	0 0708	0 4420	0 2611	0 0001	0 0018	0 0047	0 1518	0 0005	0 5034	0 0001	0 5959	0 3120
	39	39	39	40	40	40	40	40	42	40	40	40	40
SOLCA	0 70201	0 05770	0 47560	0 18049	0 36959	0 55900	0 49291	0 71402	-0 17423	0 09768	0 66580	0 20425	-0 01576
	0 0001	0 7272	0 0022	0 2651	0 0189	0 0002	0 0012	0 0001	0 2698	0 5487	0 0001	0 2061	0 9231
	39	39	39	40	40	40	40	40	42	40	40	40	40
SOLMG	0 73996	0 26255	0 30618	-0 07209	-0 40319	0 63388	0 57200	0 49694	0 50928	-0 04761	0 77166	0 15895	-0 14166
	0 0001	0 1064	0 0580	0 6584	0 0099	0 0001	0 0001	0 0011	0 0006	0 7705	0 0001	0 3273	0 3832
	39	39	39	40	40	40	40	40	42	40	40	40	40
SOLK	0 71605	0 27093	0 27998	-0 09168	0 45602	0 61592	0 55681	0 45842	0 51766	0 05864	0 75110	0 14876	0 14732
	0 0001	0 0953	0 0843	0 5737	0 0031	0 0001	0 0002	0 0029	0 0004	0 7193	0 0001	0 3596	0 3643
	39	39	39	40	40	40	40	40	42	40	40	40	40
SOLNA	0 67474	0 28082	0 23914	0 11939	0 52888	0 58406	0 52954	0 39804	-0 52473	0 07418	0 71421	-0 13254	0 15422
	0 0001	0 0833	0 1426	0 4631	0 0005	0 0001	0 0004	0 0110	0 0004	0 6492	0 0001	0 4149	0 3420
	39	39	39	40	40	40	40	40	42	40	40	40	40

	OX2	OX3	OX2_3	C_A	TOTALN	CA	MG	K	NA	(	|		NO3
SOLP	0 76182 0 0001 39	0 10886 0 5095 39	0 47139 0 0025 39	0 13650 0 4010 40	0 27105 0 1705 40	0 61884 0 0001 40	0 54067 0 0002 40	0 71892 0 0001 40	0 26502 0 0899 42	0 07191 0 6592 40	0 74089 0 0001 40	0 209 0 0 1945 40	0 04577 0 7792 40
	CL	SA	AIRMAX	AIRMIN	AIRAVE	RHMAX	RHMIN	RHAVE	TSMAX	TSMIN	TSAV	SSMAX	SSMIN
OX2	0 26532 0 1026 39	-0 23888 0 1430 39	0 59825 0 0001 39	0 27176 0 0942 39	0 51682 0 0008 39	0 07867 0 6340 39	0 69774 0 0001 39	0 56263 0 0002 39	0 07041 0 6702 39	0 30314 0 0607 39	0 17239 0 2940 39	0 71984 0 0001 39	0 70116 0 0001 39
OX3	0 12287 0 4562 39	0 10590 0 5211 39	0 29020 0 0731 39	0 27336 0 0922 39	0 29260 0 0707 39	0 23960 0 1418 39	0 27589 0 0891 39	0 24201 0 0713 39	0 23786 0 1448 39	-0 27748 0 0872 39	0 25771 0 1132 39	0 26977 0 0967 39	0 27505 0 0901 39
OX2_3	0 08200 0 6197 39	0 07839 0 6352 39	0 17216 0 2946 39	0 05869 0 7227 39	0 10820 0 5121 39	0 17221 0 2945 39	0 26131 0 1081 39	-0 14345 0 3836 39	-0 17677 0 2817 39	0 03892 0 8140 39	0 11877 0 4714 39	0 28397 0 0798 39	0 26472 0 1034 39
C_A	0 07487 0 6461 40	0 06682 0 6821 40	0 15882 0 3277 40	-0 25199 0 1167 40	0 19070 0 2385 40	0 27684 0 0837 40	0 10474 0 5201 40	0 17377 0 2836 40	-0 27753 0 0829 40	0 24626 0 1256 40	-0 26690 0 0959 40	0 08879 0 5859 40	-0 10240 0 5295 40
TOTALN	0 50879 0 0008 40	0 48035 0 0017 40	0 62805 0 0001 40	0 82693 0 0001 40	0 70339 0 0001 40	0 85443 0 0001 40	0 49064 0 0013 40	0 66401 0 0001 40	0 85451 0 0001 40	0 81742 0 0001 40	0 84740 0 0001 40	0 44929 0 0037 40	0 48449 0 0015 40
CA	0 38444 0 0143 40	0 34192 0 0308 40	0 52379 0 0005 40	0 26240 0 1019 40	0 45887 0 0029 40	0 10704 0 5109 40	0 60189 0 0001 40	0 49545 0 0012 40	0 10037 0 5377 40	0 28759 0 0720 40	0 18255 0 2596 40	0 61880 0 0001 40	0 60452 0 0001 40
MG	0 15465 0 3407 40	0 18838 0 2444 40	0 47734 0 0018 40	0 24726 0 1240 40	0 42060 0 0069 40	0 10907 0 5029 40	0 54484 0 0003 40	0 45261 0 0034 40	0 10312 0 5266 40	0 26958 0 0925 40	0 17633 0 2764 40	0 55925 0 0002 40	0 54709 0 0003 40
K	0 54791 0 0003 40	0 48221 0 0016 40	0 29849 0 0614 40	-0 04530 0 7813 40	0 20323 0 2085 40	0 21514 0 1825 40	0 43086 0 0055 40	-0 25573 0 1112 40	0 22201 0 1686 40	0 01585 0 9227 40	-0 13501 0 4062 40	0 46432 0 0025 40	0 43591 0 0049 40
NA	0 06256 0 7014 40	-0 04361 0 7893 40	0 52391 0 0004 42	0 44164 0 0034 42	0 51193 0 0005 42	0 36476 0 0175 42	0 52172 0 0004 42	0 51973 0 0004 42	0 36113 0 0188 42	-0 45260 0 0026 42	-0 40401 0 0080 42	-0 51660 0 0005 42	-0 52109 0 0004 42
SC	0 17465 0 2811 40	0 18630 0 2497 40	0 09614 0 5551 40	0 14683 0 3659 40	0 11373 0 4847 40	0 15949 0 3256 40	0 06597 0 6859 40	0 10441 0 5214 40	0 15983 0 3246 40	-0 14381 0 3760 40	-0 15456 0 3410 40	0 05701 0 7268 40	-0 06466 0 6918 40
P	0 25245 0 1161 40	0 19239 0 2343 40	0 64363 0 0001 40	0 33282 0 0359 40	0 56695 0 0001 40	-0 14626 0 3678 40	0 73490 0 0001 40	-0 61021 0 0001 40	0 13822 0 3950 40	0 36297 0 0213 40	0 23706 0 1408 40	0 75441 0 0001 40	0 73795 0 0001 40
S	0 71111 0 0001 40	0 68808 0 0001 40	0 10528 0 5179 40	-0 00747 0 9635 40	0 07869 0 6293 40	0 04265 0 7938 40	0 14140 0 3841 40	0 09340 0 5665 40	0 04471 0 7841 40	-0 01604 0 9218 40	0 01885 0 9081 40	0 15033 0 3545 40	0 14275 0 1796 40

	CL	SA	AIRMAX	AIRMIN	AIRAVE	RHMAX	RHMIN	RHAVE	TSMAX	TSMIN	TSAVE	SSMAX	SSMIN
HOJ	0 28944 0 0701 40	0 14662 0 3666 40	0 16145 0 3196 40	-0 15800 0 3302 40	-0 16450 0 3104 40	0 14230 0 3811 40	0 15074 0 3532 40	0 15324 0 3142 40	0 14146 0 3839 40	0 15979 0 3247 40	-0 15089 0 3527 40	0 14652 0 3670 40	-0 15015 0 3551 40
CL	1 00000 0 0000 40	0 98524 0 0001 40	0 21070 0 1919 40	0 39578 0 0115 40	0 27136 0 0903 40	-0 45439 0 0032 40	-0 11122 0 4945 40	-0 23892 0 1376 40	0 45628 0 0031 40	0 38341 0 0146 40	0 42949 0 0057 40	0 08254 0 6126 40	0 10700 0 5111 40
SA	0 98524 0 0001 40	1 00000 0 0000 40	0 23901 0 1375 40	0 40183 0 0102 40	0 29374 0 0658 40	0 44866 0 0037 40	0 14742 0 3640 40	0 26459 0 0990 40	0 45006 0 0036 40	0 39146 0 0125 40	0 42939 0 0057 40	0 12065 0 4583 40	0 14349 0 3771 40
AIRMAX	0 21070 0 1919 40	0 23901 0 1375 40	1 00000 0 0000 42	0 88512 0 0001 42	0 98994 0 0001 42	0 75557 0 0001 42	-0 97614 0 0001 42	0 99789 0 0001 42	0 74929 0 0001 42	0 90284 0 0001 42	0 82265 0 0001 42	0 96097 0 0001 42	0 97413 0 0001 42
AIRMIN	0 39578 0 0115 40	0 40183 0 0102 40	0 88512 0 0001 42	1 00000 0 0000 42	0 94205 0 0001 42	-0 97361 0 0001 42	-0 76296 0 0001 42	0 91344 0 0001 42	0 97139 0 0001 42	0 99922 0 0001 42	0 99272 0 0001 42	0 72183 0 0001 42	0 75707 0 0001 42
AIRAVE	0 27136 0 0903 40	0 29374 0 0658 40	0 98994 0 0001 42	0 94205 0 0001 42	1 00000 0 0000 42	0 84064 0 0001 42	0 93561 0 0001 42	0 99703 0 0001 42	0 83544 0 0001 42	0 95459 0 0001 42	0 89480 0 0001 42	0 91217 0 0001 42	0 93237 0 0001 42
RHMAX	0 45439 0 0032 40	-0 44866 0 0037 40	0 75557 0 0001 42	0 97361 0 0001 42	0 84064 0 0001 42	1 00000 0 0000 42	0 59530 0 0001 42	0 79647 0 0001 42	0 99995 0 0001 42	0 96382 0 0001 42	0 99401 0 0001 42	-0 54485 0 0002 42	0 58800 0 0001 42
RHMIN	-0 11122 0 4945 40	-0 14742 0 3640 40	-0 97614 0 0001 42	-0 76296 0 0001 42	-0 93561 0 0001 42	0 59530 0 0001 42	1 00000 0 0000 42	0 96000 0 0001 42	0 58762 0 0001 42	-0 78793 0 0001 42	0 67957 0 0001 42	-0 99811 0 0001 42	0 99996 0 0001 42
RHAVE	-0 23892 0 1376 40	0 26459 0 0990 40	0 99789 0 0001 42	-0 91344 0 0001 42	-0 99703 0 0001 42	0 79647 0 0001 42	0 96000 0 0001 42	1 00000 0 0000 42	-0 79067 0 0001 42	-0 92883 0 0001 42	-0 85779 0 0001 42	0 94100 0 0001 42	-0 95743 0 0001 42
TSMAX	0 45628 0 0031 40	0 45006 0 0036 40	0 74929 0 0001 42	0 97139 0 0001 42	0 83544 0 0001 42	0 99995 0 0001 42	0 58762 0 0001 42	0 79067 0 0001 42	1 00000 0 0000 42	0 96124 0 0001 42	0 99292 0 0001 42	0 53683 0 0002 42	0 58026 0 0001 42
TSMIN	0 38341 0 0146 40	0 39146 0 0125 40	0 90284 0 0001 42	0 99922 0 0001 42	0 95459 0 0001 42	0 96382 0 0001 42	-0 78793 0 0001 42	0 92883 0 0001 42	0 96124 0 0001 42	1 00000 0 0000 42	0 98718 0 0001 42	0 74865 0 0001 42	0 78232 0 0001 42
TSAVE	0 42949 0 0057 40	0 42939 0 0057 40	0 82265 0 0001 42	0 99272 0 0001 42	0 89480 0 0001 42	0 99401 0 0001 42	0 67957 0 0001 42	0 85779 0 0001 42	0 99292 0 0001 42	0 98718 0 0001 42	1 00000 0 0000 42	0 63325 0 0001 42	0 67299 0 0001 42
SSMAX	0 08254 0 6126 40	0 12065 0 4583 40	0 96097 0 0001 42	0 72183 0 0001 42	0 91217 0 0001 42	0 54485 0 0002 42	0 99811 0 0001 42	0 94100 0 0001 42	0 53683 0 0002 42	0 74865 0 0001 42	0 63325 0 0001 42	1 00000 0 0000 4	0 99861 0 0001 42

	CL	SA	AIRMAX	AIRMIN	AIRAVE	RHMAX	RHMIN	RHAVE	TSMAX	TSMIN	T AVE	S AX	S MIN
SSMIN	0 10700 0 5111 40	0 14349 0 3771 40	0 97413 0 0001 42	0 75707 0 0001 42	0 93237 0 0001 42	0 58800 0 0001 42	0 99996 0 0001 42	0 95743 0 0001 42	0 58026 0 0001 42	0 78232 0 0001 42	0 67289 0 0001 42	0 99963 0 0001 42	1 00000 0 0000 42
SSAVE	0 09409 0 5636 40	0 13145 0 4188 40	0 96751 0 0001 42	0 73870 0 0001 42	0 92201 0 0001 42	0 56539 0 0001 42	-0 99933 0 0001 42	0 94907 0 0001 42	0 55750 0 0001 42	0 76479 0 0001 42	0 65217 0 0001 42	0 99970 0 0001 42	0 99962 0 0001 4
RP	0 07964 0 6252 40	-0 11793 0 4686 40	0 95924 0 0001 42	0 71753 0 0001 42	0 90961 0 0001 42	0 53964 0 0002 42	0 99771 0 0001 42	0 93889 0 0001 42	0 53159 0 0003 42	-0 74452 0 0001 42	0 62844 0 0001 42	-0 99998 0 0001 42	-0 99829 0 0001 42
RAD	0 18946 0 2417 40	0 21963 0 1733 40	0 99886 0 0001 42	0 86187 0 0001 42	0 98205 0 0001 42	0 72339 0 0001 42	-0 98540 0 0001 42	-0 99365 0 0001 42	0 71678 0 0001 42	0 88125 0 0001 42	0 79453 0 0001 42	0 97310 0 0001 42	0 98382 0 0001 42
WIND	-0 25460 0 1129 40	-0 27871 0 0816 40	0 99483 0 0001 42	-0 92782 0 0001 42	0 99919 0 0001 42	0 81821 0 0001 42	0 94903 0 0001 42	0 99932 0 0001 42	-0 81269 0 0001 42	-0 94185 0 0001 42	-0 87615 0 0001 42	-0 92790 0 0001 42	-0 94614 0 0001 42
SOLCA	0 36423 0 0209 40	0 31752 0 0459 40	0 24470 0 1183 42	-0 23461 0 1348 42	0 10508 0 5078 42	0 45026 0 0028 42	-0 44980 0 0028 42	-0 18130 0 2505 42	-0 45875 0 0022 42	0 19598 0 2136 42	-0 34996 0 0231 42	0 50340 0 0007 42	0 45748 0 0023 42
SOLMG	0 05281 0 7462 40	0 09274 0 5692 40	0 94153 0 0001 42	0 67659 0 0001 42	0 88441 0 0001 42	-0 49069 0 0010 42	-0 99223 0 0001 42	-0 91770 0 0001 42	0 48236 0 0012 42	0 70519 0 0001 42	0 58300 0 0001 42	0 99800 0 0001 42	0 99331 0 0001 42
SOLK	0 08772 0 5904 40	0 12549 0 4404 40	0 96397 0 0001 42	0 72944 0 0001 42	0 91664 0 0001 42	0 55409 0 0001 42	-0 99873 0 0001 42	-0 94469 0 0001 42	0 54613 0 0002 42	0 75593 0 0001 42	0 64177 0 0001 42	0 99994 0 0001 42	0 99915 0 0001 42
SOLNA	0 13782 0 3964 40	0 17211 0 2883 40	0 98700 0 0001 42	0 79882 0 0001 42	0 95434 0 0001 42	0 64046 0 0001 42	-0 99835 0 0001 42	-0 97450 0 0001 42	0 63311 0 0001 42	0 82199 0 0001 42	0 72058 0 0001 42	0 99294 0 0001 42	0 99779 0 0001 42
SOLP	0 29666 0 0631 40	0 24793 0 1230 40	-0 42378 0 0052 42	0 04641 0 7704 42	0 29139 0 0612 42	0 27314 0 0801 42	0 61034 0 0001 42	0 36414 0 0178 42	0 28230 0 0701 42	0 00686 0 9656 42	0 16635 0 2924 42	0 65782 0 0001 42	-0 61750 0 0001 42

	SSAVE	RP	RAD	WIND	SOLCA	SOLMG	SOLK	SOLNA	SOLP
OX2	0 71126 0 0001 39	0 72193 0 0001 39	0 62273 0 0001 39	-0 54118 0 0004 39	0 70201 0 0001 39	0 73996 0 0001 39	0 71605 0 0001 39	0 67474 0 0001 39	-0 76182 0 0001 39
OX3	0 27233 0 0935 39	0 26910 0 0976 39	0 28813 0 0753 39	0 29251 0 0708 39	0 05770 0 7272 39	0 26255 0 1064 39	-0 27093 0 0953 39	-0 28082 0 0833 39	0 10886 0 5095 39
OX2_3	0 27500 0 0902 39	0 28620 0 0773 39	0 19270 0 2399 39	0 12673 0 4420 39	0 47560 0 0027 39	0 30618 0 0580 39	0 27998 0 0843 39	0 23914 0 1426 39	-0 47139 0 0025 39

	SSAVB	BP	RAD	WIND	SOLCA	SOLMG	SOLK	SOLNA	SOLP
C_A	-0 09523 0 5589 40	0 08716 0 5928 40	-0 14745 0 3639 40	0 18199 0 2611 40	0 18049 0 2651 40	-0 07209 0 6584 40	0 09168 0 5737 40	-0 11939 0 4631 40	0 13650 0 4010 40
TOTALB	-0 46549 0 0025 40	0 40394 0 0041 40	-0 60004 0 0001 40	0 68332 0 0001 40	0 36959 0 0189 40	0 40319 0 0099 40	-0 45602 0 0031 40	-0 52888 0 0005 40	0 22105 0 1705 40
CA	-0 61227 0 0001 40	0 62038 0 0001 40	-0 54319 0 0003 40	0 47834 0 0018 40	0 55900 0 0002 40	0 63388 0 0001 40	-0 61592 0 0001 40	0 58406 0 0001 40	0 61884 0 0001 40
MG	0 55370 0 0002 40	0 56059 0 0002 40	0 49420 0 0012 40	-0 43765 0 0047 40	0 49291 0 0012 40	0 57200 0 0001 40	0 55681 0 0002 40	0 52954 0 0004 40	0 54867 0 0002 40
K	0 45108 0 0035 40	-0 46759 0 0024 40	0 32904 0 0382 40	-0 23084 0 1518 40	0 71402 0 0001 40	0 49694 0 0011 40	0 45842 0 0029 40	0 39804 0 0110 40	0 71892 0 0001 40
NA	-0 51889 0 0004 42	0 51597 0 0005 42	-0 52558 0 0004 42	0 51638 0 0005 42	0 17423 0 2698 42	0 50928 0 0006 42	0 51766 0 0004 42	0 52473 0 0004 42	0 26502 0 0899 42
SC	-0 06063 0 7101 40	0 05610 0 7310 40	-0 08982 0 5815 40	0 10894 0 5034 40	0 09768 0 5487 40	0 04761 0 7705 40	-0 05864 0 7193 40	0 07418 0 6492 40	0 07191 0 6592 40
P	0 74689 0 0001 40	-0 75622 0 0001 40	0 66642 0 0001 40	-0 59000 0 0001 40	0 66580 0 0001 40	0 77166 0 0001 40	0 75110 0 0001 40	0 71421 0 0001 40	0 74089 0 0001 40
S	-0 14680 0 3660 40	0 15120 0 3517 40	-0 11371 0 4848 40	0 08644 0 5959 40	-0 20425 0 2061 40	-0 15895 0 3273 40	-0 14876 0 3596 40	0 13254 0 4149 40	0 20950 0 1945 40
NO3	0 14828 0 3612 40	0 14607 0 3685 40	-0 15971 0 3249 40	0 16397 0 3120 40	0 01576 0 9231 40	0 14166 0 3332 40	-0 14732 0 3643 40	0 15422 0 3420 40	0 04577 0 7792 40
CL	0 09409 0 5636 40	0 07964 0 6252 40	0 18946 0 2417 40	0 25460 0 1129 40	0 36423 0 0209 40	0 05281 0 7462 40	0 08772 0 5904 40	0 13782 0 3964 40	0 29666 0 0631 40
SA	0 13145 0 4188 40	0 11793 0 4686 40	0 21963 0 1733 40	0 27871 0 0816 40	0 31752 0 0459 40	0 09274 0 5692 40	0 12549 0 4404 40	0 17211 0 2883 40	0 24791 0 1230 40
ALKMAX	0 96751 0 0001 42	0 95924 0 0001 42	0 99886 0 0001 42	0 99483 0 0001 42	0 24470 0 1103 42	0 98153 0 0001 42	0 96397 0 0001 42	0 90700 0 0001 42	0 42178 0 00 2 42

	SSAVE	BP	RAD	WIND	SOLCA	SOLMG	SOLK	OINA	OLP
AIRMIN	0.73870 0.0001 42	0.71753 0.0001 42	0.86187 0.0001 42	0.92782 0.0001 42	0.23461 0.1348 42	0.67659 0.0001 42	0.72944 0.0001 42	0.79882 0.0001 42	0.04641 0.7704 42
AIRAVE	0.92201 0.0001 42	0.90961 0.0001 42	0.98205 0.0001 42	0.99919 0.0001 42	0.10508 0.5078 42	0.88441 0.0001 42	0.91664 0.0001 42	0.95434 0.0001 42	0.29139 0.0612 42
RHMAX	0.56539 0.0001 42	0.53964 0.0002 42	-0.72339 0.0001 42	0.81821 0.0001 42	0.45026 0.0028 42	-0.49069 0.0010 42	0.55409 0.0001 42	0.64046 0.0001 42	-0.27314 0.0801 42
RHMIN	0.99933 0.0001 42	0.99771 0.0001 42	-0.98540 0.0001 42	0.94903 0.0001 42	-0.44940 0.0028 42	0.99223 0.0001 42	-0.99873 0.0001 42	0.99835 0.0001 42	0.61034 0.0001 42
RHAVE	-0.94907 0.0001 42	0.93889 0.0001 42	-0.99365 0.0001 42	0.99932 0.0001 42	-0.18130 0.2505 42	0.91770 0.0001 42	-0.94469 0.0001 42	0.97450 0.0001 42	0.36414 0.0178 42
TSMAX	0.55750 0.0001 42	-0.53159 0.0003 42	0.71678 0.0001 42	0.81269 0.0001 42	-0.45875 0.0022 42	0.48236 0.0012 42	0.54613 0.0002 42	0.63311 0.0001 42	0.28230 0.0701 42
TSMIN	0.76479 0.0001 42	-0.74452 0.0001 42	0.88125 0.0001 42	0.94185 0.0001 42	-0.19598 0.2136 42	0.70519 0.0001 42	0.75593 0.0001 42	0.82199 0.0001 42	0.00686 0.9656 42
TSAVE	0.65217 0.0001 42	-0.62844 0.0001 42	0.79453 0.0001 42	-0.87615 0.0001 42	-0.34996 0.0231 42	0.58300 0.0001 42	0.64177 0.0001 42	0.72058 0.0001 42	0.16635 0.2924 42
SSMAX	0.99970 0.0001 42	-0.99998 0.0001 42	0.97310 0.0001 42	-0.92790 0.0001 42	0.50340 0.0007 42	0.99800 0.0001 42	0.99994 0.0001 42	0.99294 0.0001 42	-0.65782 0.0001 42
SSMIN	0.99962 0.0001 42	-0.99829 0.0001 42	0.98382 0.0001 42	-0.94614 0.0001 42	0.45748 0.0023 42	0.99331 0.0001 42	0.99915 0.0001 42	0.99779 0.0001 42	-0.61750 0.0001 42
SSAVE	1.00000 0.0000 42	-0.99952 0.0001 42	0.97849 0.0001 42	-0.93682 0.0001 42	0.48191 0.0012 42	0.99613 0.0001 42	0.99991 0.0001 42	0.99557 0.0001 42	-0.63903 0.0001 42
BP	-0.99952 0.0001 42	1.00000 0.0000 42	-0.97165 0.0001 42	0.92557 0.0001 42	0.50874 0.0006 42	-0.99837 0.0001 42	0.99985 0.0001 42	-0.99219 0.0001 42	0.66248 0.0001 42
RAD	0.97849 0.0001 42	-0.97165 0.0001 42	1.00000 0.0000 42	-0.98883 0.0001 42	0.29077 0.0617 42	0.95656 0.0001 42	0.97558 0.0001 42	0.99355 0.0001 42	0.46659 0.0018 42

	SSATB	BP	RAD	WIND	SOLCA	SOLMG	SOLK	SOLNA	SOLP
WIND	0 93682 0 0001 42	0 92557 0 0001 42	-0 98883 0 0001 42	1 00000 0 0000 42	-0 14494 0 3597 42	0 90244 0 0001 42	-0 93196 0 0001 42	0 96557 0 0001 42	0 32958 0 0331 42
SOLCA	0 48191 0 0012 42	0 50874 0 0006 42	0 29077 0 0617 42	-0 14494 0 3597 42	1 00000 0 0000 42	0 55707 0 0001 42	0 49381 0 0009 42	0 39736 0 0092 42	-0 98193 0 0001 42
SOLMG	0 99613 0 0001 42	0 99837 0 0001 42	0 95656 0 0001 42	-0 90244 0 0001 42	0 55707 0 0001 42	1 00000 0 0000 42	0 99723 0 0001 42	0 98344 0 0001 42	0 70417 0 0001 42
SOLK	0 99991 0 0001 42	0 99985 0 0001 42	0 97558 0 0001 42	0 93196 0 0001 42	0 49381 0 0009 42	0 99723 0 0001 42	1 00000 0 0000 42	0 99419 0 0001 42	0 64946 0 0001 42
SOLNA	0 99557 0 0001 42	0 99219 0 0001 42	0 99355 0 0001 42	-0 96557 0 0001 42	0 39736 0 0092 42	0 98344 0 0001 42	0 99419 0 0001 42	1 00000 0 0000 42	0 56385 0 0001 42
SOLP	0 63903 0 0001 42	0 66248 0 0001 42	-0 86659 0 0018 42	0 32958 0 0331 42	0 98193 0 0001 42	-0 70417 0 0001 42	0 64946 0 0001 42	0 56385 0 0001 42	1 00000 0 0000 42

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