**Dedicated in the Loving Memory of my best friend Late Ranjeet**

---- KAKA MORE

# INVESTIGATIONS ON THE CHEMICAL COMPOSITION IN BULBS OF FOUR GARLIC CULTIVARS AS INFLUENCED BY TWO STORAGE METHODS

By

**Kakasaheb Mahadeo More**

(Reg. No. 93136)

A Thesis Submitted to the

**MAHATMA PHULE KRISHI VIDYAPEETH**

RAHURI 413 722 DIST.-AHMEDNAGAR

Maharashtra State (India)

in partial fulfilment of the requirements for the degree

of

**MASTER OF SCIENCE (AGRICULTURE)**

in

**BIOCHEMISTRY**



DEPARTMENT OF BIOCHEMISTRY

POST GRADUATE INSTITUTE

MAHATMA PHULE KRISHI VIDYAPEETH

RAHURI, DIST- AHMEDNAGAR, M. S.(INDIA)

**1996**

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Approved

Dr. S.V. Mujal.
Research Guide

Dr. B. B. Desai.
Committee Member

Dr. K.E. Lawande.
Committee Member

Prof. J. G. Patil
Committee Member

DEPARTMENT OF BIOCHEMISTRY,
MAHATMA PHULE KRISHI VIDYAPEETH,
POST GRADUATE INSTITUTE,
RAHURI-413 722.

1996

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## CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
thereof has not been submitted
by me or any other person to
any other University
or Institute for
a Degree or
Diploma.

Place : MPKV, Rahuri.

Dated : 18/7/1996.

(K. M. MORE)

**********

**DR. S.V. MUNJAL**
Associate Professor of Biochemistry,
Post-Graduate Institute,
Mahatma Phule Krishi Vidyapeeth,
Rahuri - 413 722, Dist. Ahmednagar,
Maharashtra, India.

# CERTIFICATE

This is to certify that the thesis entitled, **"INVESTIGATIONS ON THE CHEMICAL COMPOSITION IN BULBS OF FOUR GARLIC CULTIVARS AS INFLUENCED BY TWO STORAGE METHODS"**, submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **BIOCHEMISTRY**, embodies the results of a piece of *bona fide* research work carried out by **SHRI MORE KAKASAHEB MAHADEO**, under my guidance and supervision and no part of the thesis has been submitted for any other degree, diploma or publication in any other form.

The assistance and help received during the course of this investigation has been duly acknowledged.

S.V. Munjal.

Place : MPKV, Rahuri.
Dated : १८ / ०७ / 1996.

(S.V. MUNJAL)
Research Guide

**DR. L.P. KAMBLE**
Associate Dean,
Post Graduate Institute,
Mahatma Phule Krishi Vidyapeeth,
Rahuri - 413 722, Dist: Ahmednagar,
Maharashtra, India.

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Place : MPKV, Rahuri.
Dated : 23/7/1996.

L.P. Kamble
(L.P. KAMBLE)

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Place : MPKV, Rahuri
Dated : 18 / 7 /1996.

(K.M. More)

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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| °C | : | Degree celcius |
| C.D. | : | Critical differences |
| Cv | : | Cultivar |
| et al. | : | et alli (and others) |
| etc. | : | Etcetera |
| Fig. | : | Figure |
| fr. wt. | : | Fresh weight |
| g | : | Gram |
| Gy | : | Gyrationsyards |
| ha | : | Hectare |
| hr | : | Hour |
| kg | : | Kilogram |
| km | : | Kilometer |
| mg | : | Milligram |
| M.H. | : | Maleic hydrazide |
| min | : | Minutes |
| mm | : | Milimeter |
| % | : | Per cent |
| rh | : | Relative humidity |
| S.E. | : | Standard error |
| viz. | : | Videlicet (namely) |
| UV | : | Ultra violet |

# Abstract

# ABSTRACT

**INVESTIGATIONS ON THE CHEMICAL COMPOSITION IN BULBS OF FOUR GARLIC CULTIVARS AS INFLUENCED BY TWO STORAGE METHODS**

By

More K.M.

A candidate for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

1996

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Major Professor : Dr. S.V. Munjal

Department : Biochemistry

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An experiment was conducted under ambient conditions to study the effects of two storage methods on the chemical composition of garlic bulbs of four cultivars stored upto 135 days after the April harvest of 1995. The cultivars selected for the present study were: Godawari, Jamnagar, Rahuri Local and Sweta. Garlic bulbs of the fresh harvest were stored on farm with tops by hanging and with tops on ground in bundles in a well ventilated room. The moisture content in the garlic

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bulbs of all the four cultivars, subjected to above two storage methods, decreased steadily over a period of 135 days. The results further revealed that there was a greater

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**Abstract Contd....** **More K.M.**

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cultivars, measured by difference,did not change significantly during the storage upto 135 days by both the methods.

The sulphur content, however, increased in the garlic bulbs of all the four cultivars during storage upto 135 days, the increase being more in the bulbs stored on ground than in the bulbs stored by hanging method. Based on the results obtained in the present investigation, it can be concluded that the above-mentioned four garlic cultivars can be stored better even at the ambient temperature with tops by hanging in a well ventilated room than with tops on the ground in bundles.

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Pages 1 to 64.

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# Introduction

# 1. INTRODUCTION

The genus *Allium* contains more than 500 species, most of which are bulbous, possessing characteristic pungent odours. The most important cultivated Alliums are onion (*Allium cepa* L.), garlic (*A. sativum* L.), leek (*A. fistulosum* L.), rakkyo (*A. chimena* L.), chives (*A. schoenoprasum* L.) and shallot (*A. ascalonicum* L.) (Anonymous, 1985). Onions, garlic and other cultivated *alliums* have long been recognized for their culinary properties and flavour. Some Alliums, notably garlic and onion, have a history of medicinal usage, and their consumption has also had considerable religious significance. Garlic has important medicinal properties against digestive disorders, eye sore and earache (Subrahmanyan et al., 1958).

Garlic is rich in carbohydrates, proteins and minerals like phosphorus, and magnesium (Shinde and Sontakke, 1986). According to Roychwodhary (1963), analysis of garlic (dry) gave the following values : moisture, 62.0; protein, 6.3; fat, 0.1; fibre, 0.8; carbohydrates, 29.8; and minerals, 0.1 g/100g; calcium, 30.0; phosphorus 310.0; iron, 1.3; thiamine, 0.06; riboflavin, 0.23; niacin, 0.4; and vitamin C, 13.0 mg/100g. The folic acid content was found to

be 6.15; and iodine 0.07 mg/100g. Its caloric value is 145 Kcal/100 g. The characteristic odour of garlic is due to the volatile oil which consists of a large number of sulphur compounds like sulphide, disulphide, trisulphide, etc. (Shankarnarayana et al., 1981). The volatile sulphur compounds are formed due to rupturing, leading in the reactions between the enzymes lyase/alliinase and the flavour precursors.

Garlic is a frost hardy bulbous perennial herb. It has flat narrow leaves and bears small white flowers and bulbils. It is a herbaceous annual for the bulb production and biennial for the seed production. The edible underground stem is the composite bulb made up of a number of segments known as cloves. The number of cloves ranges from 12 to 20 or more. They are enclosed in a white or light pink coloured sheath (Bose and Som, 1990).

The origin of garlic is said to be central Asia and southern Europe, specially Mediteranean region (Thompson and Kelly, 1957). The area under garlic in the world is reported to be 5.28 lakh ha with annual production of 29.3 lakh tonnes of bulbs. According to FAO production year book of 1995 in India, garlic crop covers an area of 79,000 ha. yielding approximately 2.93 lakh tonnes of bulbs.

Unlike onion, garlic is grown mainly during the winter season and its requirements are in everyday use. It has, therefore, become imperative to store the bulbs till the next season. It has been reported that losses to the tune of 23 to 62% occur in different garlic cultivars during storage in our country (Anonymous, 1987).

In Maharashtra, generally traditional methods of storage are used, viz., storage of garlic in bamboo baskets, storage with tops by hanging and storage with tops on ground in bundles. During storage period, garlic may shrink, lose water and dry matter through desiccation and transpiration processes, and may additionally be damaged by rotting, adverse conditions may encourage sprouting, etc.

The treatment of garlic bulbs with about 50 Gy of $^{60}Co$ gamma rays approximatdy 30 days after harvest can inhibit sprouting and reduce weight losses during storage (Ceci et al., 1991). The irradiation process applied to garlic bulbs did not affect the flavour.

Several chemical changes occur in the composition of garlic bulbs during storage at ambient temperature which have direct effect on storability of garlic bulbs. It was

therefore desired to study the storability of four garlic cultivars in relation to their compositional changes during storage. Garlic with dried leaves is normally stored by hanging in well ventilated room at ambient temperature. Refrigerated storage is too expensive in many tropical countries to be considered financially viable for crops of comparatively low value like garlic. To study the relation between the chemical parameters and the keeping quality of garlic bulbs, two methods of storage were employed. The present study was restricted to the following main objectives :

1. To estimate the proximate composition in the bulbs of four garlic cultivars, and

2. To evaluate the effects of methods of storage on the chemical composition of four garlic cultivars as assessed periodically upto 135 days.

# Review of Literature

# 2. REVIEW OF LITERATURE

Garlic (*Allium sativum* L.) is one of the most important spice cropsof India as well as of the world. It is grown all over India and occupies 4,400 ha area in Maharashtra (Anonymous, 1988). It is grown mainly during winter season and therefore, it becomes imperative to store the bulbs till the next season. Garlic with dried leaves is stored by hanging in India. However, very little work has been reported on storage of garlic bulbs in India. Various physico-chemical changes take place during storage of garlic. The literature available on the biochemical changes during storage of Alliums and related matter is reviewed in this chapter.

Composition of garlic as adopted from Pruthi (1979) is as follows :

**Table 1. Composition of garlic bulbs.**

| Sr. No. | Particular | Fresh peeled garlic cloves | Dehydrated garlic powder |
|---|---|---|---|
| 1. | Moisture, % | 62.80 | 5.20 |
| 2. | Protein, % | 6.30 | 17.50 |
| 3. | Fat, % | 0.10 | 0.60 |
| 4. | Ash, % | 1.00 | 3.20 |
| 5. | Fibre, % | 0.80 | 1.90 |
| 6. | Carbohydrates, % | 29.00 | 71.40 |

## 2.1 Moisture

The average moisture content in peeled garlic bulbs varies from 61.0 to 63.0 per cent. Pruthi (1979) reported that the average moisture content in garlic bulbs was up to 62.8 per cent. The average moisture content has been reported as 62.0 per cent (Roychowdary, 1963) and 61.3 per cent (Anonymous, 1985). Fenwick and Hanley (1990) reported that garlic has an exceptionally high dry matter content from 30 to 56% depending on cultivars, than other *Alliums*.

The lower moisture content of onion bulbs has been correlated with better keeping quality (Salunkhe and Desai, 1984). Kodic (1971) found that the onion varieties with high dry matter content stored well and retained their aroma better than those varieties having low dry matter. It has been reported that higher dry matter of onion bulbs causes less sprouting during storage (Foskett and Peterson, 1950).

Omar and Arafa (1978) applied 2500 or 5000 ppm maleic hydrazide (MH) as foliar spray two weeks before harvest and observed inhibition of sprouting in storage upto 300 days without any appreciable adverse effect on yield of garlic. This treatment also reduced the loss in weight of the bulb

during storage. Butarin (1958) also observed a strong correlation between dry matter and keeping quality. Cultivars having high dry matter content can be stored for longer periods than those having low dry matter (Jones and Mann, 1963; Toul and Pospisilara, 1968).

## 2.2 Crude protein

Garlic is rich in protein content. The average crude protein content is 6.3% of fresh peeled garlic cloves (bulblets) and 17.50% of dehydrated garlic powder (Pruthi, 1979). The effect of $\gamma$-irradiation and storage in garlic cv. Belady cloves has been studied by El-Warraki et al. (1970) and also by Guo et al. (1981). They have further reported the effects on the amino acid composition of garlic. The levels of lysine, arginine, methionine, phenylalanine and norleucine all appeared to increase, while remaining amino acids decreased. There have been many studies on the occurrence and content of S-containing amino acids in *Allium* species. There is a positive correlation between the flavour compounds and S-containing amino acids (Ceci et al., 1991).

Magdum (1981) found that protein, in general, was positively correlated with the total sugar losses due to

sprouting, rotting and shrinkage. Singh and Kumar (1969) observed gradual increase in protein content and total N during storage. Similar observations were recorded earlier by Karmarkar and Joshi (1941).

## 2.3 Crude fat

Comparatively little work has been done on the lipid content of garlic. Pruthi (1979) reported that the average fat content in garlic is 0.10% and 0.60% in fresh peeled garlic cloves (bulblets) and dehydrated garlic powder, respectively.

The role of crude fat in the keeping quality of garlic has not been investigated. However, the higher crude fat content of onion bulbs has been correlated with their better keeping quality (Aksoy, 1983). Stoinova-Ivanova and Tzutzulova (1974) investigated free and bound fatty acid content of garlic flesh.

Kammana and Chandrasekhara (1980) isolated 600 mg lipids/100 g fresh weight from garlic cloves using chloroform methods and further separated these to yield neutral lipids, glycolipid and phosphodipid fraction. Yang and Shin (1982)

isolated 310 to 342 mg lipids/100 g in garlic but found rather different amounts on fractionation. Khade (1985) reported that crude fat content of onions decreased slightly during storage.

## 2.4 Ash content

Ash content in garlic bulbs has been reported as 1.00 g/100 g in fresh peeled garlic cloves. However, it is 3.20 g/100 g in dehydrated garlic powder (Pruthi, 1979).

Roychowdhary (1963) has also reported 1.0 per cent ash content in garlic bulbs. Ash content and dry matter has a positive correlation (Raj and Agrawal, 1980). The observations by Basker (1975) indicated that the percent ash in the onion solids increased appreciably with time and offered this parameter for the weight loss during storage.

Prehavest treatment to onion bulbs with maleic hydrazide has been found to prevent losses in ash content during storage (Gorin and Borcsok, 1980). A high dry matter content (% dry matter) is important in onions used for dehydration and processing (Darbyshire and Henzy, 1979).

## 2.5 Crude fibre

Crude fibre, mainly cellulose and lignin, is a non-available carbohydrate. As the ability of the body to digest and assimilate cellulose is exceedingly limited, its use in the diet is not to supply energy but to give bulk and thus to provide material for certain regulatory processes such as elimination of waste from the intestines.

Pruthi (1979) reported 0.80 and 1.90% of crude fibre in fresh peeled garlic cloves and dehydrated garlic powder, respectively. Analysis of garlic (dry) gave 0.8% crude fibre (Roychowdhary, 1963).

## 2.6 Carbohydrates

The main component of the solids content in garlic bulbs is carbohydrate, the exact proportion varying considerably among cultivars. Pruthi (1979) reported that garlic contains 29.0% of carbohydrates in fresh peeled and 71.40% in dehydrated garlic powder.

Non-structural carbohydrates account for the major portion of the dry weight of the garlic and is composed of free sugars, trisaccharides and a group of larger molecular

eight species fructans (Bennett, 1941). Srinivasan et al. 1953) reported that content of glucose, fructose and sucrose n garlic as 1.2%, 1.4% and 7.0%, respectively. risaccharides viz., 1-β - fructofuranosyl (1-ketose) and -β - fructo furanosyl have been reported to be present in arlic (Darbyshire and Henzy, 1978).

Various studies have revealed that the storage of arlic has only little effect on dry weight content alothough he relative proportion of reducing and nonreducing sugars ary greatly.

**Sulphur**

*Alliums* have been prized for their flavour and ungency for many centuries and so it is not surprising that a reat deal is now known about the chemical structures, roperties and biosynthetic origin of the compounds esponsible for these desirable properties. Pungency in *llium* is very much attributed to sulphur content of the pecies (Kwon and Yoon, 1985).

Levels of sulphus components in garlic depends greatly upon exogenous sulphate fertilization and aslo supon he plant part examined as reported by Granroth (1970). The

sulphur content in garlic bulbs is significantly affected due to the different levels of phosphate fertilization. Sulphur content increased with the increase in $P_2O_5$ level (Pawar and Patil, 1989)

The characteristic odour of garlic is due to the volatile oil which consists of a large number of sulphur compounds like sulphide, disulphide, trisulphide, etc.(Shankar-narayana et al., 1981). The pungency of the onion has been shown to be closely related to the keeping quality (Gilbert et al., 1963).

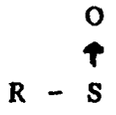
### 2.7.1 Flavour

*Alliums* are rich in sulphur-containing compounds which are broken down by endogenous enzymes to yield a wide range of more volatile, less stable chemical compounds. Intact *Alliums* have no pungency since the volatile products are only released following the interaction of the enzyme, alliinase, with the S-alkenyl cysteine sulphoxide which occurs when cells are damaged or disrupted (Fig. I). The initial products of this enzymic hydrolysis are ammonia, pyruvate and alkenyl thiosulphinate (Fig. II). This latter compound, which possesses odour characteristics typical of the freshly cut

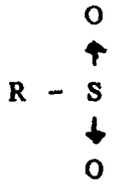
tissue, can undergo further non-enzymatic reactions to yield a range of compounds, including a thiosulphonate (Fig. III) and di and higher sulphides (Fig. IV).

**Sulphur containing flavour volatiles from alliums :**

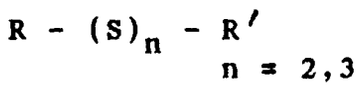
... (Fig. I)



... (Fig. II)



... (Fig. III)



... (Fig. IV)

## 2.8 Various other treatments for storage of garlic bulbs

Mathur (1963) found that $\gamma$-irradiation of garlic (50 Gy) and subsequent storage at 11 to 12°C for 7 months resulted in no adverse effect on taste, flavour, pungency, or texture. Irradiation extended the storage life of garlic by three fold (2 to 7 months). Complete inhibition of sprouting on treatment with a dose of 120 Gy and 9 months storage of

garlic was reported by Abdel-Al (1967) in contrast to 90% sprouting in the control, untreated material. When autumn and spring garlic bulbs were exposed to a dose of 0, 80, 120 or 150 Gy of $\gamma$-irradiation and stored, a dose-related beneficial effect was noted with the groups receiving the highest dose showing storage losses of 9.3% (due to sprouting, softening and rot compared to 38.4% in the controls) and 17.7% (due to sprouting, softening and rot compared to 34.6%) in the case of the autumn garlic (Salkova, 1983). Losses of 2.5% (11.6% control) and 15.1% (32.5% control), respectively, were measured in the spring crop.

For extension of storage life of garlic bulbs, packaging singly in polyethylene bags, selection of small sized bulbs, storage at 32-35°F (0 - 1.6°C) and irradiation with 6 krad of cobalt - 60 gamma rays have been recommended by Habibunisa et al. (1971). Mihailescu et al. (1979) noted that storage of garlic at 1.5°C at relative humidity (RH) < 75% reduced the storage losses to 12.2% over 150 days from 42.4% at ambient temperature. Treatment with UV light for 30 min and then storage at 1.5°C further reduced the loss to 8.6%.

The International standard for cold storage of garlic suggests that crops intended for such treatment should

be harvested, dried and packed away from all other crops except onions. Optimum storage conditions are 8 to 10 days drying in store at 20 to 30°C, followed by temperature reduction to 0°C and maintenance at 0 ± 0.5°C (R.H. 65 to 70%) with permanent air circulation. Under such condition, storage life is 130 to 220 days, depending upon such factors as cultivar type and cultivation practices. At the end of storage, the crop should be rewarmed gradually to avoid condensation (Anonymous, 1983).

## 2.9 Garlic products

Much of the work on the processing of garlic has been conducted by Pruthi and his co-workers at the Central Food Technological Research Institute, Mysore, India.

Pruthi et al. (1959) reported that only 80% of the Indian garlic crop was utilized, the wastage being due primarily to microbial contamination, respiration and transpiration. This loss was equivalent to some 4,000 ha. For this and other reasons, Pruthi and his co-workers developed a sample procedure for the manufacture of dehydrated garlic.

On the basis of chemical, microbiological and sensory evaluation, Pruthi et al. (1960) considered that 60°C

was the maximum temperature for dehydrating garlic. Storage of garlic powder was best achieved in cans while storage in sealed polythene bags proved least satisfactory. The commercially important products derived from garlic are as described below :

### 2.9.1 Dehydrated garlic

Dehydrated garlic is usually considered to possess above five times the flavour of fresh clove. While that flavour character is retained well on storage, as with dehydrated onion, it is important that the powder be stored free of moisture to prevent lumping and hardening.

Garlic powder is extensively used in the manufacture of spiced sausages. Many examples of flavouring formulations containing this and other *Allium* products have been prepared. As with other products mentioned above, processing does have a deleterious effect in removing some of the more volatile flavour components and garlic powder is reported to possess a 'boiled' quality absent in the freshly crushed clove. Processing also introduces foreign flavour qualities resulting from the partial caramalization of sugars present (Pruthi et al., 1960).

### 2.9.2 Garlic oil

Garlic contains between 0.1 and 0.25% volatile oil, considerably more than is present in onion. Distillation of freshly crushed garlic cloves yields oil of garlic, a reddish brown oil rich in 2-propanyl sulphides. In many cases, the pungency of this product is too great for efficient formulation and garlic juice, expressed in a manner similar to onion juice may be used. Further, concentration yields oleoresin garlic, a dark brown extract containing approximately 5% garlic oil and possessing 2 to 3 times the odour strength of fresh garlic (8 to 10 times that of garlic powder). The advantage of this product is its uniformity and good handling and processing characteristics. Encapsulated garlic flavours are generally spray dried products containing garlic oil, oleoresin, or extract encapsulated in gum arabic or a modified starch, the flavour being released on dissolution in water. The exact flavour strength of these products depends upon the manufacturer's formulation but generally ranges from two to four times that of garlic powder. Russian workers have recently used liquid $CO_2$ extraction to improve the quality of garlic preparations for use in sausage manufacture (Avagimov et al., 1982).

## 2.10 Uses of garlic

Garlic is most commonly used as a condiment and for flavouring and seasoning of food products such as soups, dals, pickles, etc. It is also used for flavouring vinegar or oil for dressing. Incorporation of garlic in the diet at moderate levels is likely to shift the balance of the microflora in the intestine in favour of lactic acid organisms which generally have a favourable effect on the absorption of minerals present in the diet.

Garlic is endowed with several medicinal properties. It is stimulant, diaphoretic, expectorant, diuretic and tonic. It is rubefacient when applied externally. It is used as an anthelmintic and emmenagogue. The juice of garlic is used for various ailments of the stomach including amoebic dysentry. It is also used as an anti-tubercular drug, and in the treatment of epilepsy. It is reported to be anticholeric. Garlic reduces the blood sugar levels. It is an anti-fertility drug showing oxytocic activity.

Garlic therapy in the treatment of leprosy significantly alters the bacteriological index and improves the clinical condition of the patients. Garlic is a powerful

natural cleansing and disinfecting medium. Garlic extract showed anti-bacterial activity inhibiting the growth of *Escherichia coli*, *Salmonella typhosa*, etc. The anti-bacterial activity has been shown to be due to the presence of allicin. It is, therefore, widely used both in intestinal disorders and in a number of infectious diseases. Garlic extract also has an anti-fungal effect on yeasts and moulds (Anonymous, 1985).

On the basis of the literature survey conducted, it can be concluded that garlic is an important spice crop and is grown during winter but its use being daily, has to be stored till the next season. In a tropical country like India, refrigerated storage is too expensive to be considered financially viable for this crop. Generally garlic is stored with dried leaves by hanging in a well ventilated room. With various other treatments even we can extend the storage life of garlic bulbs. Use of $\gamma$-irradiation to bulbs after harvest, treatment with UV light for 30 min., preharvest treatment with maleic hydrazide (3000 ppm), storage at controlled atmospheric conditions, etc. can be used for extension of storage life of garlic bulbs. However, these treatments are not very common in use in our country.

Garlic can even be best preserved by making various products like dehydrated garlic, garlic flavouring products like garlic juice, oleoresin garlic, garlic extract encapsulated in gum arabic or modified starch, garlic salt, etc. The characteristic odour of garlic is due to the volatile oil which consists of a large number of sulphur compounds like sulphides, disulphides, trisulphides, etc. Garlic, beside being used as a condiment and for flavouring and seasoning of food products like soups, dals, pickles, etc. has many other medicinal uses also. Garlic is a stimulant, diaphoretic, expectorant, diuretic and tonic. It reduces the blood sugar levels. It is used for various ailments of stomach, treatment of leprosy, etc.

Though garlic is not an economically important vegetable crop like onion, it is, however, of daily use in Indian kitchens. The various other post harvest treatments given to garlic bulbs do not look economically viable and hence, it was thought necessary to evaluate the performance of four garlic cultivars under two storage methods at ambient temperature during the months April to August, 1995.

# Materials and Methods

# 3. MATERIAL AND METHODS

The present investigation was planned to evaluate the effect of two storage methods on the chemcial composition of bulbs of four garlic cultivars stored at ambient temperature. The various methods adopted are detailed below :

## 3.1 Material

### 3.1.1. Garlic cultivars

Garlic cultivars were obtained from the Senior Vegetable Breeder, MPKV, Rahuri from the harvest of April, 1995.

The following cultivars were used for the present studies :

| White | Red |
|---|---|
| i) Godawari | iv) Rahuri Local |
| ii) Jamnagar | |
| iii) Sweta | |

### 3.1.2 Chemicals

Most of the chemicals used in this investigation were of analytical grade. They were obtained from Vijay Trading Corporation, Shrirampur.

## 3.2 Methods

### 3.2.1 Storage of cultivars and preparation of sample

The four garlic cultivars were stored by two methods upto 135 days at the ambient temperature after the

harvest and analyzed at an interval of 45 days for its compositional changes during storage. Storage of garlic was done in two ways: The leaves of garlic were weaved with each other to form bundles. The bundles were then stored as follows :

1. Storage with tops by hanging in a hut thatched with sugarcane trash on the farm, and

2. Storage with tops on ground in bundles in a well ventilated room.

**Preparation of a sample :**

At indicated time, about 100g bulbs of each cultivar were taken for analysis. The bulbs were peeled and then cut into small pieces with stainless steel knife and the chips were dried in constant temperature oven (60°C) to a constant weight. The dried chips were then ground in a grinder to obtain a fine powder. This powdered material was utilized for the analysis of various parameters.

**Chemical composition :**

Moisture, ash, crude fat, crude fibre and total nitrogen contents were determined according to the standard

A.O.A.C. procedures. Total carbohydrate content was calculated by difference.

### 3.2.2 Moisture content

Ten grams of peeled cloves sample was accurately weighed and dried at 60°C for 5 hours. After cooling in the desiccator it was weighed. Drying was continued for one more hour and the sample was again weighed. The drying and weighing were repeated until constant weight was obtained. The loss in weight was recorded as moisture content.

### 3.2.3 Protein content

The protein content was determined by Micro-kjeldhal Method (Anonymous, 1990)

**Reagents :**

1. Concentrated sulphuric acid (sp. gr. 1.84, N-free).
2. Catalyst mixture - Potassium sulphate, mercuric oxide and copper sulphate were weighed, 99, 4.1 and 0.8 g, respectively and mixed thoroughly.
3. Sodium hydroxide (50%) - Fifty grams of sodium hydroxide and 5 grams of sodium thiosulphate were dissolved in distilled water separately, mixed and the volume made upto 100 ml.

4. Boric acid (4%) - Four grams of boric acid was dissolved in distilled water and volume made upto 100 ml with distilled water.
5. Hydrochloric acid (0.02N) - 0.17 ml of hydrochloric acid (sp. gr. 1.18, 35%) was dissolved in distilled water and volume made upto 100 ml.
6. Hydrogen peroxide
7. Mixed indicator : Mixed indicator was prepared by dissolving 0.1 g of bromocresol green and 0.1 g of methyl red in 100 ml of 95% alcohol separately. Ten parts of bromocresol green solution and 2 parts of methyl red solution were mixed together and transferred to a bottle provided with a stopper.

**Procedure :**

Two hundred milligrams of powdered sample was accurately weighed and transferred to a digestion flask. One gram of catalyst mixture was mixed thoroughly with the sample. Five ml of concentrated sulphuric acid and 5 ml of hydrogen peroxide were carefully added and the sample was digested in a digestion chamber. Initially the flasks were heated slowly for 10 to 15 min. and then the temperature was raised

gradually so that the contents boiled briskly. The digestion was continued until the samples became clear and colourless. The flasks were then cooled and minimum quantity of water was added to dissolve the solids in the flasks. After cooling the contents, they were transferred to volumetric flasks. The digestion flasks were washed 3 to 4 times with distilled water. All the washings were transferred to volumetric flasks and volume made.

Ten ml of boric acid solution was pipetted into a 100 ml beaker and 6 to 8 drops of mixed indicator solution were added. The beaker was placed under condenser of the distillation assembly. The tip of the condenser was dipped below the surface of the solution. Five ml digest was pipetted into distillation flask and mixed with 10 ml of 50% sodium hydroxide solution. The distillation was continued to collect about 50 ml of the distillate. At the end of distillation, the tip of the condenser was washed to collect all ammonia. The distillate was then titrated with standard hydrochloric acid solution. Before distillation, the colour of boric acid plus indicator was pink which changed to blue during distillation and finally to pink red at the end of titration. Blank titration was carried out each time.

percentage of nitrogen content was calculated from the quantity of standard hydrochloric acid required for titration. The protein content was calculated by multiplying the nitrogen content by a factor of 6.25.

### 3.2.4 Crude fat content

The crude fat content was determined by ether extraction using soxhelt apparatus (Anonymous, 1990).

**Reagent :**

Petroleum ether having boiling point of 40-60°C.

**Procedure :**

Five gram of the powdered sample was accurately weighed and transferred to a thimble. The thimble was plugged with cotton and placed in extraction flask of the soxhelt apparatus. Sufficient quantity of petroleum ether was taken in preweighed dry collecting flask and the assembly was connected to tap water. The flask was heated and the temperature was regulated at 60°C. The extraction was continued till 5 to 6 siphonings were completed. It was ensured that very little quantity of ether was present in the flask. The flask was then disconnected and cooled. The contents of the flask were evaporated and flask was dried in oven. The difference in initial and final weights of the

flask was used to calculate the crude fat content of the sample.

### 3.2.5. Ash content

The method for ash content was adopted from Anonymous (1990). Five grams of powdered sample was accurately weighed into preweighed silica crucible. It was ignited in muffle furnace at about 550°C (dull red) until light gray ash results. After cooling in a desiccator to room temperature crucible was weighted. The difference in weight of the crucible after ashing and the weight of empty crucible was recorded as a measure of ash content.

### 3.2.6 Crude fibre

Crude fibre is loss on ignition of dried residue remainning after digestion of sample with 1.25% $H_2SO_4$ and 1.25% NaOH solution under specific condition (Anonymous, 1990).

**Reagents :**

1. 0.25 N sulphuric acid
2. 0.31 N sodium hydroxide
3. Ethanol

**Procedure:**

The residue obtained after crude fat determination was used. The residue was transferred to a conical flask and 200 ml of boiling sulphuric acid was added and heated for 30 min. Then the flask was removed, cooled and filtered through a muslin cloth. The residue was then washed with boiling distilled water 3 to 4 times until the residue was acid free. The residue was again transferred to a conical flask and 200 ml of boiling NaOH was added. The contents were boiled for 30 min. After 30 min the flask was cooled and filtered through muslin cloth. Three to four washings were given with distilled water to make the residue alkali free. Lastly two more washings of ethanol were given. The residue was then scraped from the cloth and transferred to the preweighed silica crucible and dried at 105°C in an oven for 2 hours. After cooling in a desiccator it waas weighed.

Drying was continued for one more hour and the sample was again weighed. The drying and weighing were repeated until constant weight was obtained. The difference in weight of crucible with residue and the weight of empty crucible was recorded as fibre content.

### 3.2.7. Carbohydrate content

Total carbohydrate content was expressed as difference after substracting the % contents of proximate principles from 100.

### 3.2.8. Sulphur content

Total sulphur was determined by wet digestion of plant tissue sample and the sulphate content in the digest was then determined by barium sulphate turbidimetry method (Tandon, 1980). During wet digestion of the samples all the plant sulphur was converted to sulphate form, which when treated with $BaCl_2$ was precipitated as white $BaSO_4$. This provides turbidity to the solution which is proportional to the amount of sulphate present.

**Reagents :**

1. Barium chloride ($BaCl_2.2H_2O$).
2. Gum acacia solution : Powdered gum acacia (0.5 g) was dissolved in a mixture containing 50 ml glacial acetic acid and 50 ml distilled water. The solution was stored in a refrigerator in order to avoid the growth of micro-organisms.

3. Salt buffer solution: It contained 50 g $MgCl_2 . 6H_2O$, 4.1 g $KNO_3$ and 28 ml ethanol/litre.
4. HCl : 6N.
5. Standard sulphur solution : To prepare 100 ppm S solution, 0.543 g of analytical grade $K_2SO_4$ was dissolved in distilled water and diluted to one litre.

**Procedure :**

**Digestion of sample :**

Diacid digestion : It was carried out by using 9:4 mixture of $HNO_3$ : $HClO_4$.

One gram of the powdered garlic sample was accurately weighed and transferred to a 100 ml conical flask. To this, 10 ml of acid mixture was added and the contents in the flask were mixed by swirling. The flask was placed on low heat hot plate in a digestion chamber. Initially the flask was heated slowly for 10-15 min and then the temperature was raised gradually so that the contents boiled briskly. The digestion was continued until the production of red $NO_2$ fumes ceased. The contents were further evaporated until the volume was reduced to about 3 to

5 ml but not to dryness. The completion of digestion was confirmed when the liquid became colourless. The flask was then cooled and 20 ml of distilled water was added, volume was made up to 100ml with distilled water and then the solution was filtered through Whatman No.1 filter paper. Aliquots of this solution were used for further determination of S.

**Estimation of sulphur :**

Ten ml of the aliquot from the digest was pipetted in a 50 ml volumetric flask. To it, 25 ml of salt buffer was added. Then 1 ml 6N HCl and 1 ml of 0.5% gum acacia solutions were added. The contents were mixed by swirling. Then 0.5 g of barium chloride crystals were added to get a turbid solution. The volume was made upto 50ml with distilled water.

The absorbance of this solution was then read on a Spectronic-20 spectrophotometer at 420 nm. Sulphur concentration was calculated from a standard curve.

**Preparation of a standard curve :**

The aliquots (0,10,20,30,40 and 50 ml) of 100 ppm S standard solution were pipetted into a separate 250 ml volumetric flasks. To this 25 ml of salt buffer was added.

The volume was made up with distilled water and mixed thoroughly. The resulting solution thus provided 0, 4, 8, 12, 16 and 20 ppm S solution, respectively.

Ten ml each of the above solutions were pipetted into 50 ml volumetric flasks. Then 1 ml of 6N HCl and 1 ml of 0.5% gum acacia solutions were added to each flask. The contents were mixed by swirling and then 0.5 g of barium chloride crystals were added and dissolved to get a turbid solution. The volume was made upto 50 ml with distilled water.

The absorbance of the solution was read on at 420 nm. The absorbance was plotted against concentration of sulphur and then a standard curve was drawn.

### 3.2.9 Statistical analysis

The data obtained in different experiments were analysed on micro computer using Factorial Completely Randomized Design (FCRD) and the standard error and critical difference were calculated.

# 4. RESULT AND DISCUSSION

The effect of two storage methods, viz. storage with tops by hanging and storage with tops on ground in bundles upto 135 days from the April harvest, were evaluated in four garlic cultivars commonly grown in the MPKV region. The four garlic cultivars selected for this study were : Godawari, Sweta, Jamnagar and Rahuri Local. The bulbs of garlic were periodically analysed for important chemical parameters during storage at 0, 45, 90 and 135 days after harvest. The results obtained are presented and briefly discussed in this section.

## 4.1 Moisture

The changes in moisture content in garlic bulbs during storage by two different storage methods are presented in Table 2 and Fig. 1 and 2. As indicated, there was a reduction in moisture content in garlic bulbs throughout the storage period. The loss of moisture in bulbs of garlic held by hanging was more than in the bulbs stored on the ground in bundles.

Significant variation in the moisture content of the bulbs of four garlic cultivars was observed (Fig. 1 and 2) which has direct effect on the storability of individual garlic

# Results and Discussion

**Table 2. Effect of storage methods on moisture content in four garlic cultivars**

| Sr. No. | Method of storage | Cultivars | Storage period, days | | | |
|---|---|---|---|---|---|---|
| | | | 0 | 45 | 90 | 135 |
| | | | Moisture, % | | | |
| 1. | Garlic bundles stored by hanging | Godawari | 58.70 | 57.80 | 57.40 | 56.75 |
| | | Jamnagar | 62.30 | 60.33 | 59.20 | 58.55 |
| | | Rahuri L | 59.70 | 58.60 | 58.20 | 57.30 |
| | | Sweta | 63.10 | 61.70 | 60.20 | 59.40 |
| 2. | Garlic bundles stored on ground | Godawari | 58.70 | 58.55 | 58.30 | 58.20 |
| | | Jamnagar | 62.80 | 61.35 | 60.10 | 60.10 |
| | | Rahuri L | 59.70 | 57.30 | 56.40 | 56.00 |
| | | Sweta | 63.10 | 62.25 | 60.20 | 59.90 |
| S.E. for cultivars | | | 0.244 | 0.442 | 0.140 | 0.158 |
| C.D. at 5% | | | 0.732 | 1.325 | 0.420 | 0.475 |
| S.E. for storage | | | 0.172 | 0.312 | 0.099 | 0.112 |
| C.D. at 5% | | | 0.157 | 0.937 | 0.297 | 0.336 |
| S.E. for Int. ± | | | 0.345 | 0.625 | 0.198 | 0.224 |
| C.D. at 5% | | | 0.103 | 1.874 | 0.595 | 0.672 |

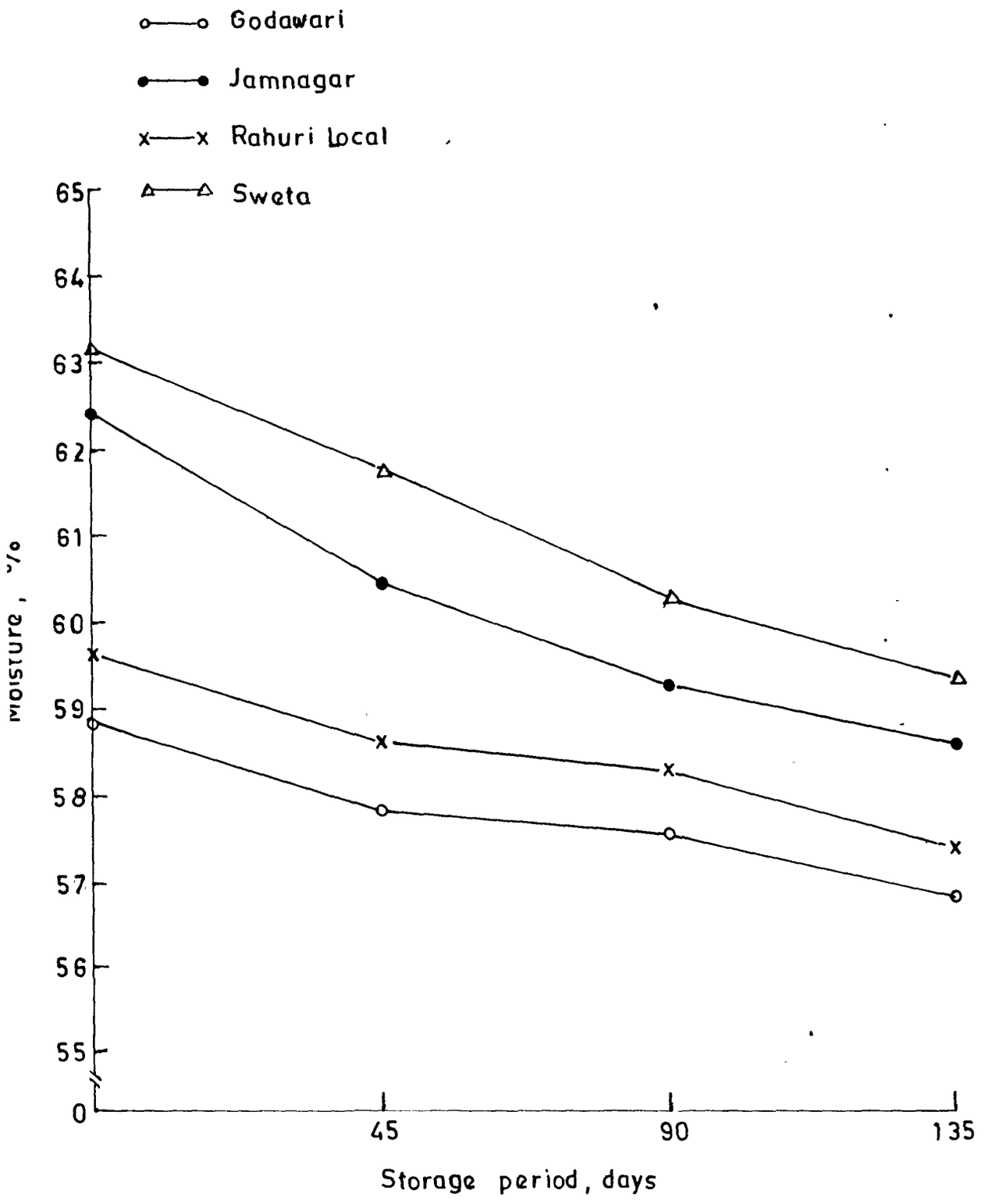
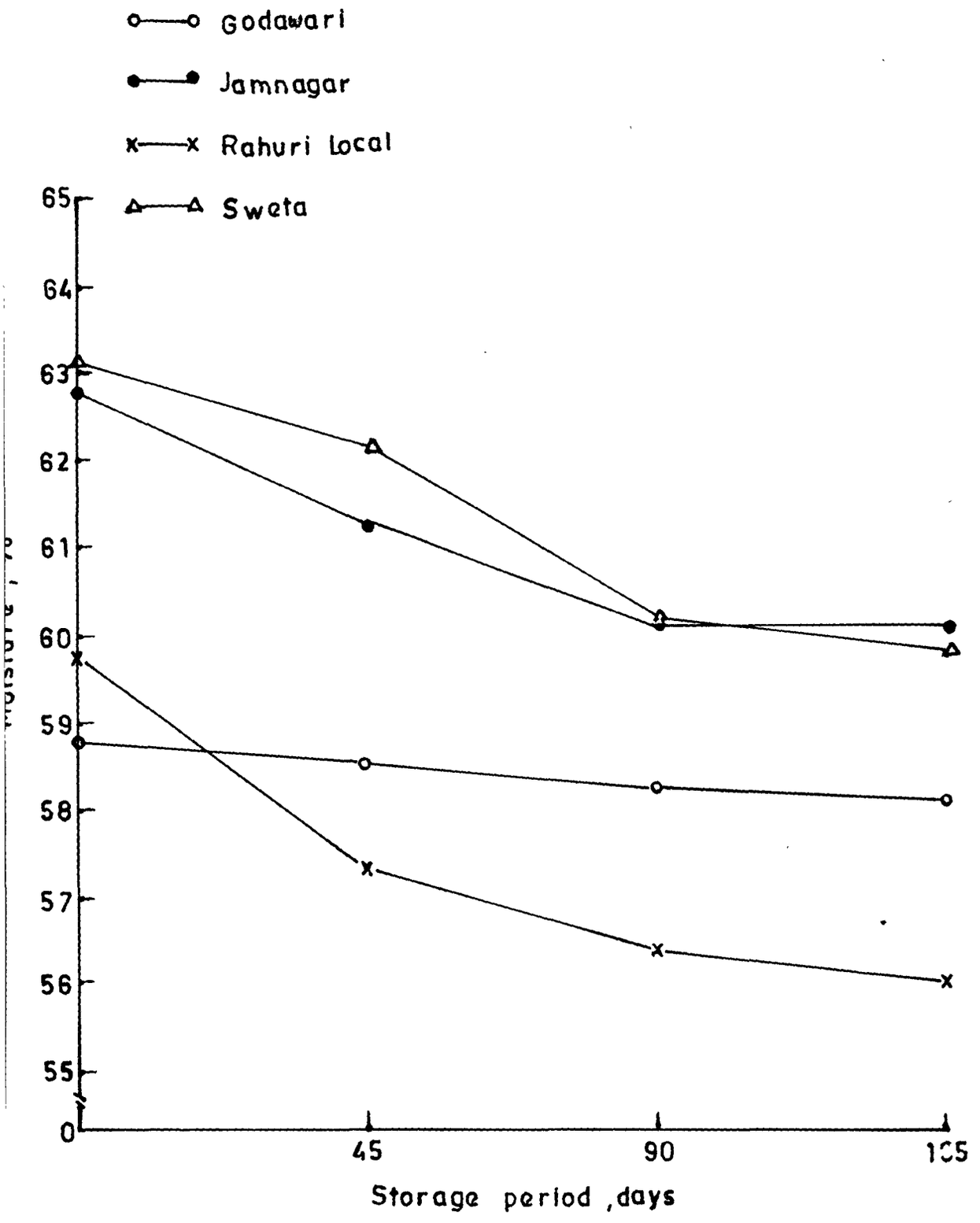



Fig. 1 Effect of storage on moisture content in the bulbs of four garlic cultivars stored with tops by hanging in bundles.



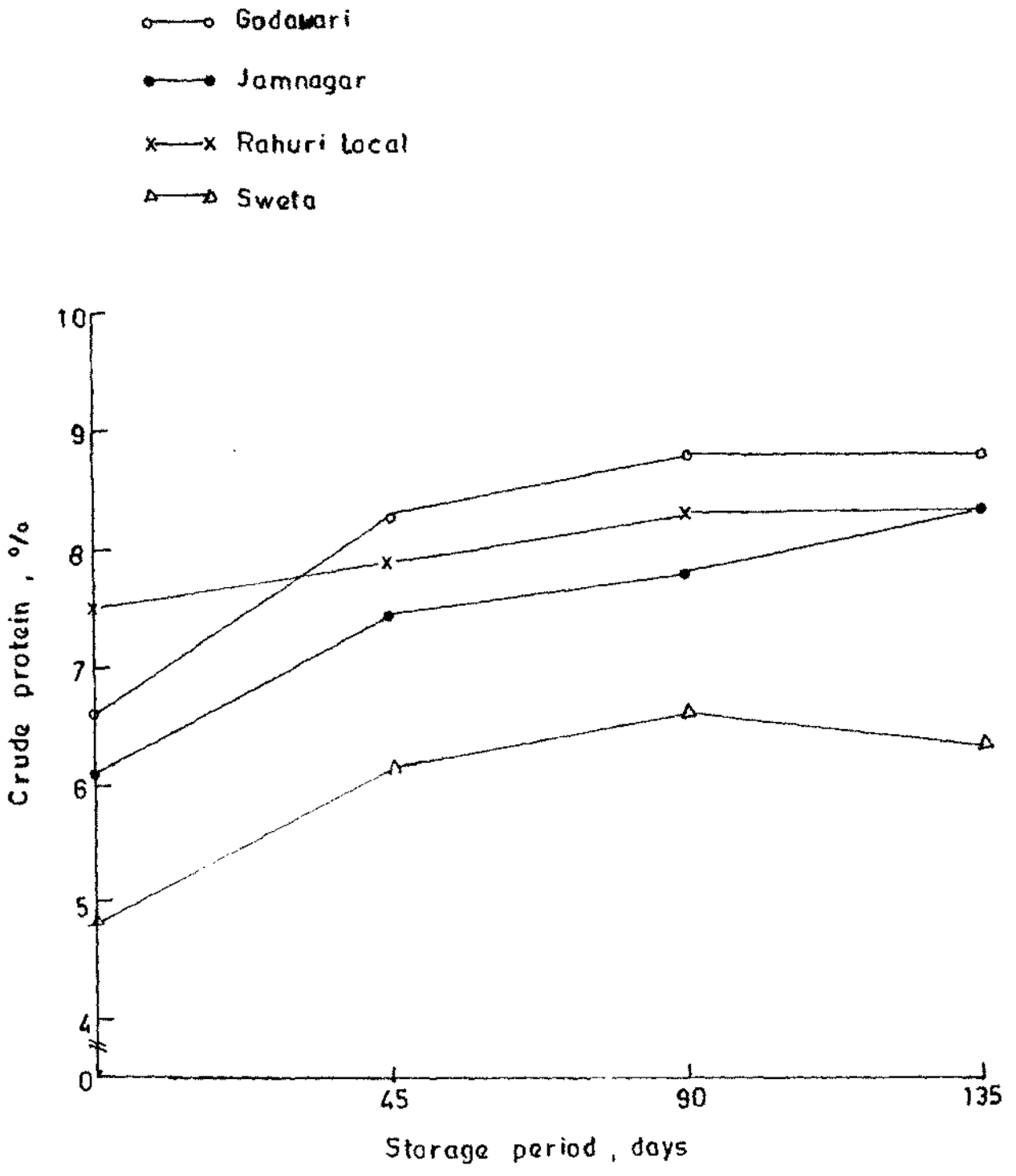

ig. 2 Effect of storage on moisture content in the bulbs of four garlic cultivars stored with tops on the ground in bundles.

cultivar. The Godawari cultivar had the lowest moisture content, and the cultivar sweta had higher moisture content than the other cultivar under study.

The loss of moisture during storage is important because it inhibits mold growth, insect infestation and thus prevent losses by rotting. Studies carried out on storage of garlic cultivars revealed that rotting losses for Godawari, Jamnagar and Sweta were 2.56%, 4.02% and 5.00%, respectively (Anonymous, 1989). Kodic (1971) found that higher dry matter content in *Alliums* stored well than low dry matter. The lower moisture content of onion bulbs has been correlated with better keeping quality (Salunkhe and Desai, 1984). Fenwick and Hanley (1990) reported that garlic had an exceptionally high dry matter content from 30 to 56% depending on cultivars than other *Allium* species. Higher dry matter of onion bulbs caused less sprouting during storage (Foskett and Peterson, 1950).

## 4.2 Crude protein

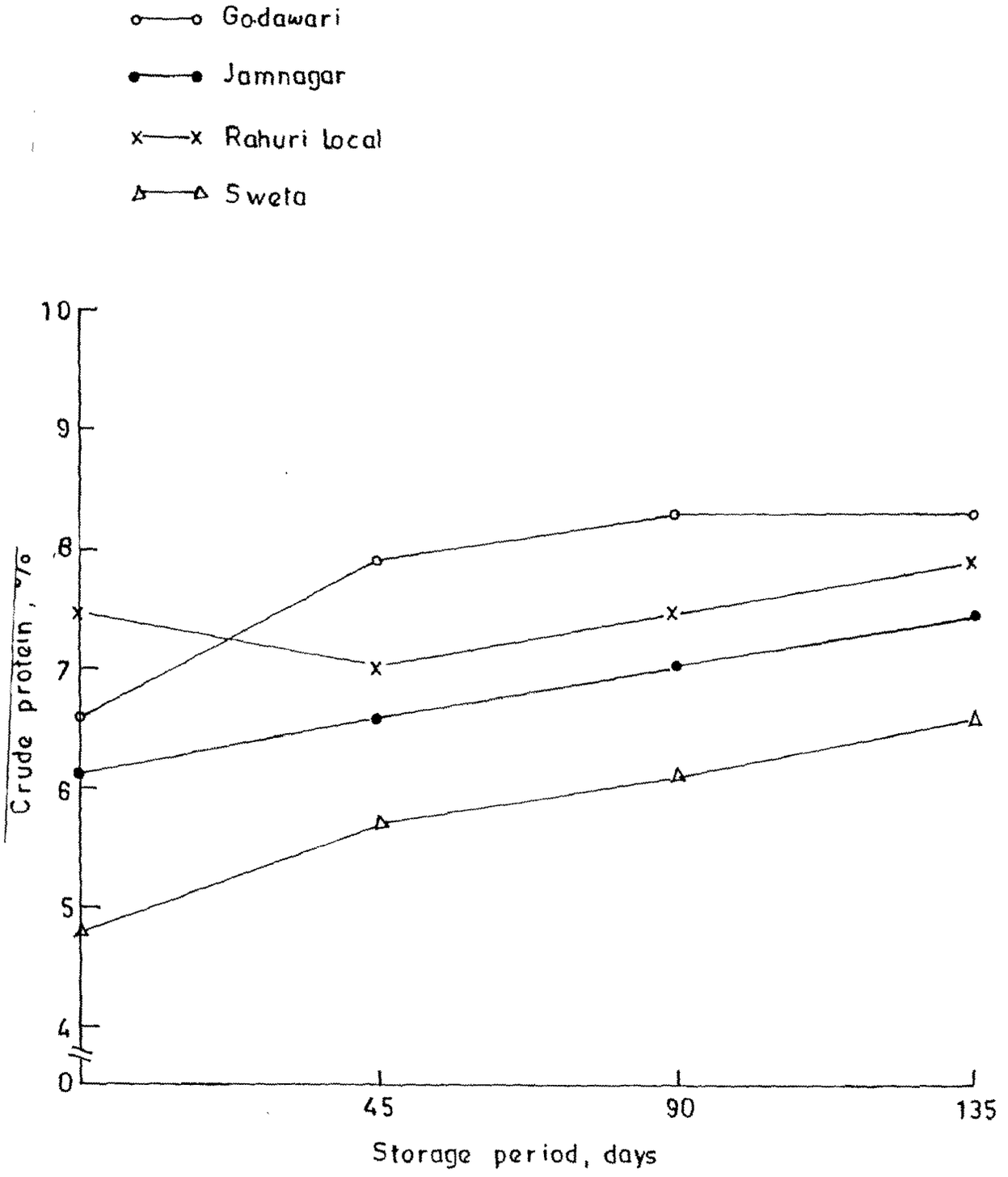
The changes in crude protein content in garlic bulbs during storage by two different methods of storage are given in Table 3 and Fig. 3 and 4. The results reveal that




3 Effect of storage on crude protein content in the bulbs of four garlic cultivars stored with tops by hanging in bundles.

Table 3. Effect of storage methods on crude protein content in four garlic cultivars

| Sr. No. | Method of storage | Cultivars | Storage period, days | | | |
|---|---|---|---|---|---|---|
| | | | 0 | 45 | 90 | 135 |
| | | | Crude protein, % | | | |
| 1. | Garlic bundles stored by hanging | Godawari | 6.57 | 8.34 | 8.79 | 8.79 |
| | | Jamnagar | 6.12 | 7.44 | 7.79 | 8.33 |
| | | Rahuri L | 7.44 | 7.89 | 8.33 | 8.33 |
| | | Sweta | 4.82 | 6.12 | 6.58 | 6.36 |
| 2. | Garlic bundles stored on ground | Godawari | 6.57 | 7.88 | 8.33 | 8.33 |
| | | Jamnagar | 6.12 | 6.58 | 7.03 | 7.44 |
| | | Rahuri L | 7.44 | 7.03 | 7.44 | 7.89 |
| | | Sweta | 4.82 | 5.68 | 6.12 | 6.58 |
| S.E. for cultivars | | | 0.155 | 0.125 | 0.129 | 0.221 |
| C.D. at 5% | | | 0.465 | 0.377 | 0.388 | 0.663 |
| S.E. for storage | | | 0.109 | 0.088 | 0.091 | 0.156 |
| C.D. at 5% | | | 0.328 | 0.266 | 0.274 | 0.469 |
| S.E. for Int. ± | | | 0.219 | 0.177 | 0.183 | 0.313 |
| C.D. at 5% | | | 0.657 | 0.533 | 0.549 | 0.938 |




4 Effect of storage on crude protein content in the bulbs of four garlic cultivars stored with tops on the ground in bundles.

the crude protein content in garlic cultivars increased gradually during storage. It was also observed that the protein content in the bulbs of garlic was more in bundles hanged than those stored on the ground.

The data further indicate the comparative efficacy of two storage methods on the behaviour of four garlic cultivars in their chemical parameters. It is seen that protein content is more in bulbs stored by hanging method than the other method. It is further observed that Godawari cultivar has more protein content as compared to other three cultivars.

Singh and Kumar (1969) observed gradual increase in protein content and total N during storage of onion. Similar observations were earlier recorded by Karmarkar and Joshi (1941). The protein content of onion bulbs generally increased with the advancement of storage period. The lower protein content of the onion bulbs has been shown to be correlated with its better keeping quality. (Toul and Pospisilara, 1968).

A study has been conducted on the post harvest treatment of $\gamma$ -irradiation and storage on amino acid

composition of garlic. The levels of lysine, arginine, methionine, phenylalanine and norleucine all appeared to increase following irradiation (250 Gy), while remaining amino acids all decreased (El-Warrakki et al., 1978). However, Chinese workers have found the soluble carbohydrates, lipids and proteins of garlic to be unaffected by irradiation doses of less than 500 Gy and storage periods in excess of 2 months (Guo et al., 1981).

## 4.3 Crude fat

The changes in the crude fat content in the bulbs of garlic cultivars during storage upto 135 days from harvest are given in Table 4 and Fig. 5 and 6.

The crude fat content of freshly cured bulbs of garlic is 0.65, 0.65, 0.60 and 0.55 for Godawari, Jamnagar, Rahuri Local and Sweta, respectively. As observed from the Fig. 5 and 6, the crude fat content in garlic bulbs gradually decreased during storage. This observation is very much similar to that made by Khade (1985) during the storage of onion bulbs. Figures also show that Godawari has the highest crude fat content, whereas the Sweta the lowest. It is also seen that crude fat content is higher in the garlic

**Table 4. Effect of storage methods on crude fat content in four garlic cultivars**

| Sr. No. | Method of storage | Cultivars | Storage period, days | | | |
|---|---|---|---|---|---|---|
| | | | 0 | 45 | 90 | 135 |
| | | | Crude fat, % | | | |
| 1. | Garlic bundles stored by hanging | Godawari | 0.65 | 0.55 | 0.40 | 0.35 |
| | | Jamnagar | 0.65 | 0.60 | 0.55 | 0.40 |
| | | Rahuri L | 0.60 | 0.50 | 0.45 | 0.40 |
| | | Sweta | 0.55 | 0.45 | 0.45 | 0.35 |
| 2. | Garlic bundles stored on ground | Godawari | 0.65 | 0.55 | 0.45 | 0.45 |
| | | Jamnagar | 0.65 | 0.55 | 0.40 | 0.35 |
| | | Rahuri L | 0.60 | 0.50 | 0.40 | 0.30 |
| | | Sweta | 0.55 | 0.50 | 0.45 | 0.35 |
| S.E. for cultivars | | | 0.017 | 0.025 | 0.031 | 2.880 |
| C.D. at 5% | | | 0.053 | 0.074 | 0.094 | 8.650 |
| S.E. for storage | | | 0.012 | 0.017 | 0.022 | 2.041 |
| C.D. at 5% | | | 0.037 | 0.053 | 0.066 | 6.121 |
| S.E. for Int. ± | | | 0.025 | 0.035 | 0.049 | 4.080 |
| C.D. at 5% | | | 0.074 | 0.106 | 0.133 | 1.224 |

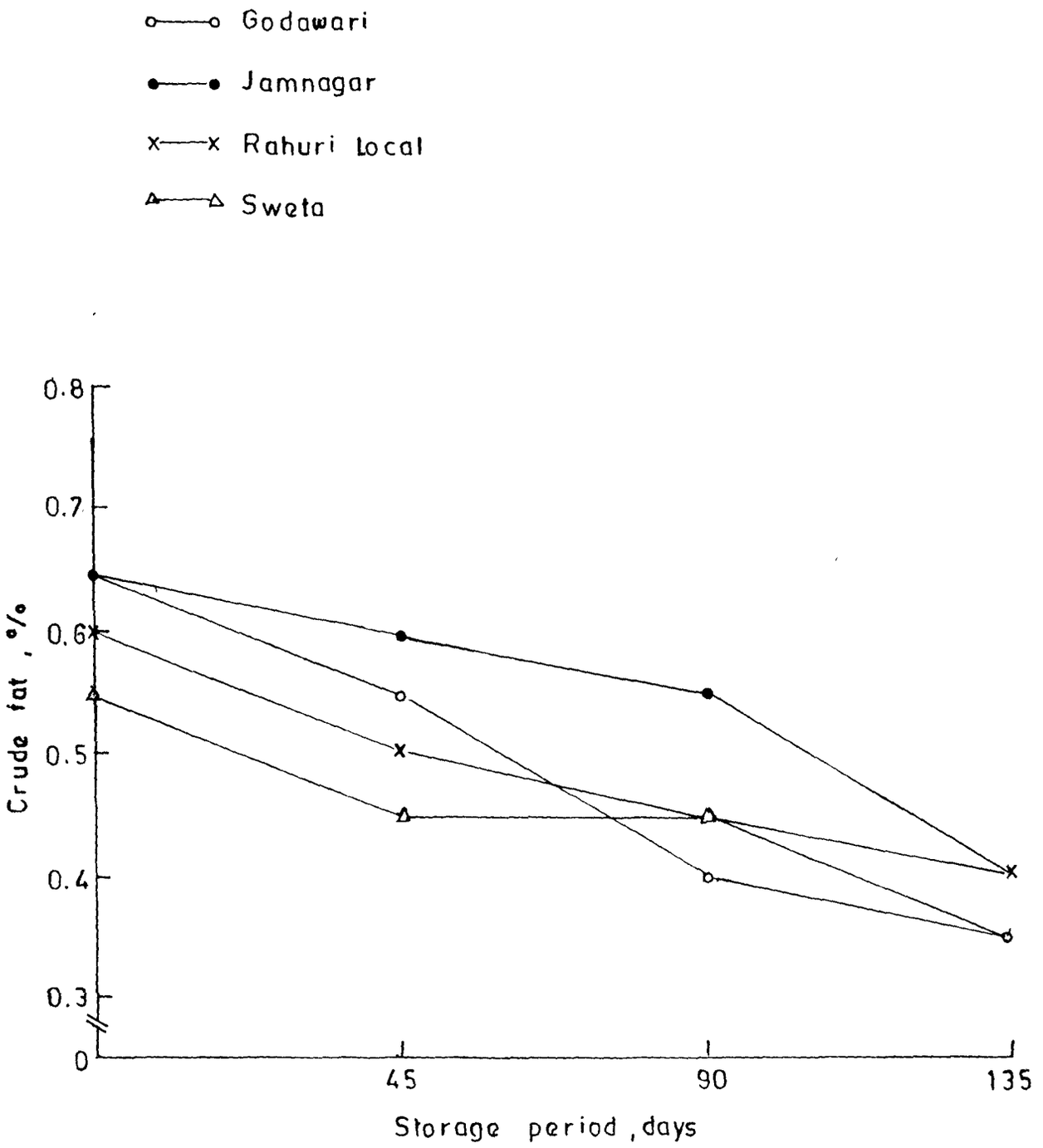



Fig. 5 Effect of storage on crude fat content in the bulbs of four garlic cultivars stored with tops by hanging in bundles.

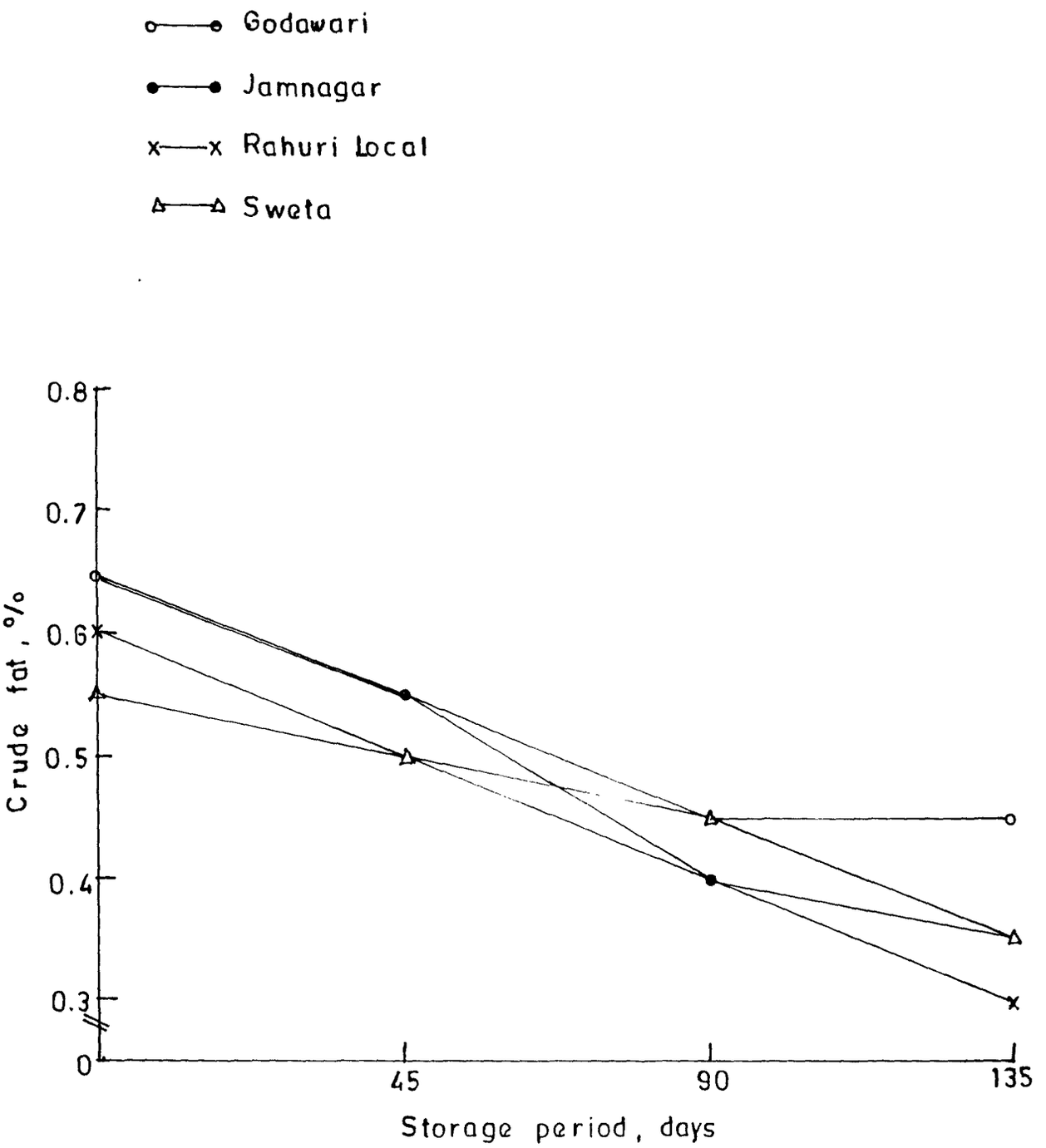



Fig. 6 Effect of storage on crude fat content in the bulbs of four garlic cultivars stored with tops on the ground in bundles.

bulbs held in bundles stored by hanging method than in the bundles kept on the ground. The role of crude fat on the keeping quality of onion and garlic has not been investigated fully. However, the higher crude fat content of onion bulbs has been correlated with their better keeping quality (Aksoy, 1983). Aksoy (1983) further reported that oil content of Imrati and Kantartopu onion cultivars increased on storage (3-7 months) from 0.016-0.01 and 0.031-0.047 ml/100 g, respectively. Khade (1985), however, reported that crude fat content of onions increased slightly during storage.

Chinese workers have found the soluble lipids of garlic to be unaffected by irradiation doses of less than 500 Gy and storage periods in excess of 2 months (Guo et al., 1981).

## 4.4 Ash content

The changes in ash content in garlic bulbs during storage by two different storage methods are given in Table 5 and Fig. 7 and 8. The results reveal that the ash content in garlic bulbs increases gradually during storage. It was also observed that the ash content increased slightly in the same proportion in the bulbs of garlic stored by both the methods.

**Table 5. Effect of storage methods on ash content in four garlic cultivars**

| Sr. No. | Method of storage | Cultivars | Storage period, days | | | |
|---|---|---|---|---|---|---|
| | | | 0 | 45 | 90 | 135 |
| | | | Ash, % | | | |
| 1. | Garlic bundles stored by hanging | Godawari | 1.50 | 2.30 | 2.40 | 2.30 |
| | | Jamnagar | 1.30 | 2.30 | 2.40 | 2.33 |
| | | Rahuri L | 1.20 | 2.10 | 2.30 | 2.20 |
| | | Sweta | 1.10 | 1.90 | 1.90 | 1.80 |
| 2. | Garlic bundles stored on ground | Godawari | 1.50 | 2.10 | 2.40 | 2.30 |
| | | Jamnagar | 1.30 | 2.00 | 2.16 | 2.16 |
| | | Rahuri L | 1.20 | 1.40 | 2.16 | 2.20 |
| | | Sweta | 1.10 | 1.60 | 2.20 | 1.90 |
| S.E. for cultivars | | | 0.035 | 0.877 | 0.133 | 0.105 |
| C.D. at 5% | | | 0.106 | 0.263 | 0.398 | 0.316 |
| S.E. for storage | | | 0.024 | 0.062 | 0.094 | 0.074 |
| C.D. at 5% | | | 0.074 | 0.186 | 0.282 | 0.223 |
| S.E. for Int. $\pm$ | | | 0.049 | 0.124 | 0.188 | 0.149 |
| C.D. at 5% | | | 0.149 | 0.372 | 0.564 | 0.446 |

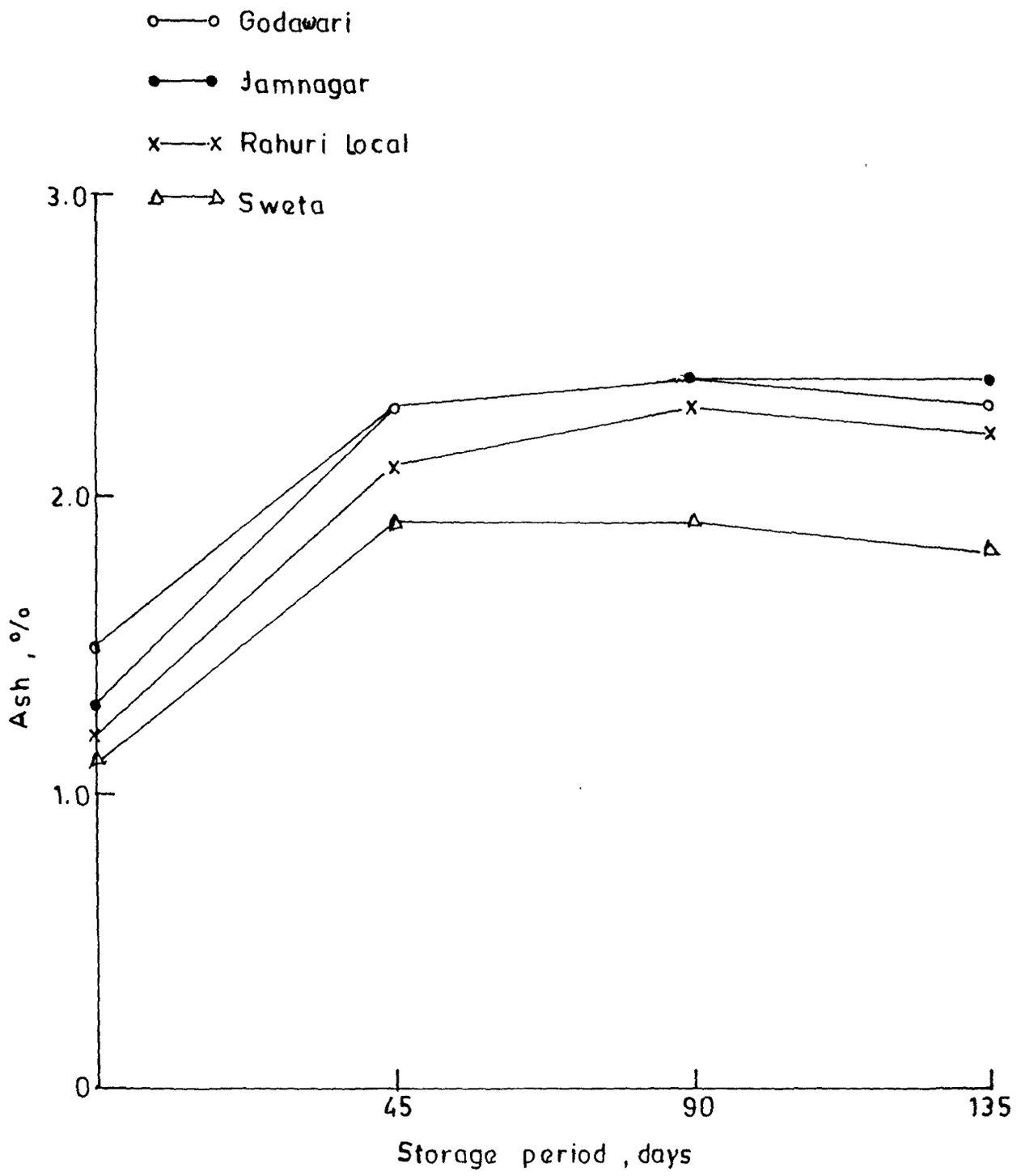



Fig. 7 Effect of storage on ash content in the bulbs of four garlic cultivars stored with tops by hanging in bundles.

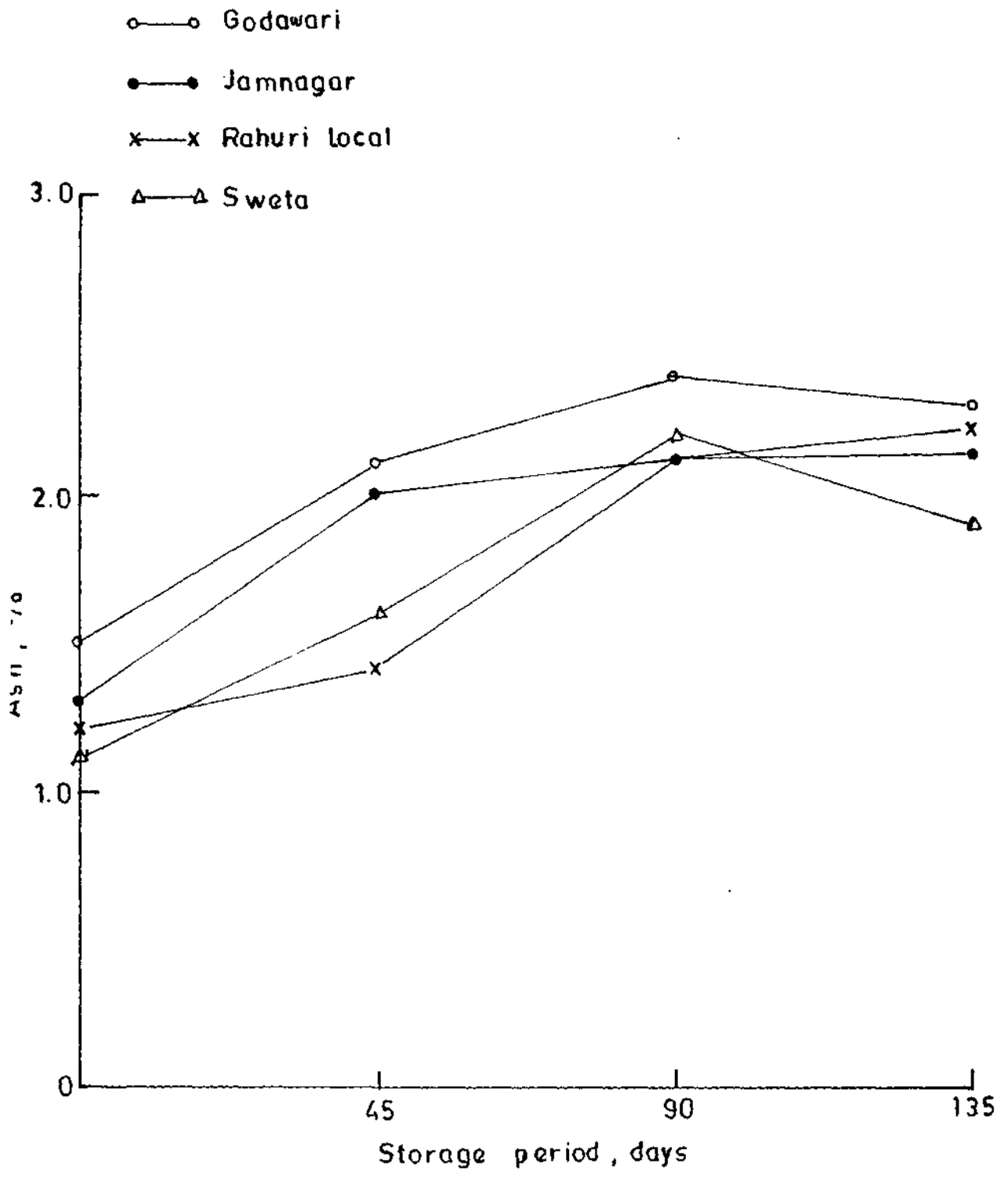



Fig. 8 Effect of storage on ash content in the bulbs of four garlic cultivars stored with tops on the ground in bundles.

The figures further show the comparative ash content of all the cultivars. Godawari has highest ash content than other cultivars used in this study.

The report by Basker (1975) found that the per cent ash of the onion solids increased appreciably with time and offered this as a parameter for the measurement of weight loss on storage. Gorin and Borcsok (1980) have studied that the ash content of untreated cv. Hyduro onions increased from 0.39 to 0.52% (fr. wt. ) over 252 days of storage than preharvest treatment with maleic hydrazide to onion bulbs which caused the ash content to remain constant during the same period of storage.

The report in onion indicated that high pungency is usually found with high dry matter content. Although this is often associated with good storage quality, it is yet to be determined whether high pungency has a direct effect on storage performance, for example, by inhibiting attack by micro organisms (Smittle, 1988).

## 4.5 Crude fibre

Crude fibre which is mainly cellulose and lignin is a nonavailable carbohydrate for human diet. The use of crude

**Table 6. Effect of storage methods on crude fibre content in four garlic cultivars**

| Sr. No. | Method of storage | Cultivars | Storage period, days | | | |
|---|---|---|---|---|---|---|
| | | | 0 | 45 | 90 | 135 |
| | | | Crude fibre, % | | | |
| 1. | Garlic bundles stored by hanging | Godawari | 1.25 | 1.75 | 2.25 | 2.00 |
| | | Jamnagar | 0.75 | 1.50 | 2.00 | 1.75 |
| | | Rahuri L | 1.00 | 1.75 | 2.00 | 2.00 |
| | | Sweta | 0.50 | 1.25 | 1.25 | 1.75 |
| 2. | Garlic bundles stored on ground | Godawari | 1.25 | 1.50 | 1.75 | 1.75 |
| | | Jamnagar | 0.75 | 1.00 | 1.25 | 1.50 |
| | | Rahuri L | 1.00 | 1.75 | 1.50 | 1.50 |
| | | Sweta | 0.50 | 0.75 | 1.25 | 1.25 |
| S.E. for cultivars | | | 0.072 | 0.181 | 0.148 | 0.161 |
| C.D. at 5% | | | 0.210 | 0.544 | 0.446 | 0.483 |
| S.E. for storage | | | 0.051 | 0.128 | 0.105 | 0.114 |
| C.D. at 5% | | | 0.153 | 0.385 | 0.315 | 0.342 |
| S.E. for Int. ± | | | 0.102 | 0.256 | 0.210 | 0.228 |
| C.D. at 5% | | | 0.306 | 0.770 | 0.630 | 0.684 |

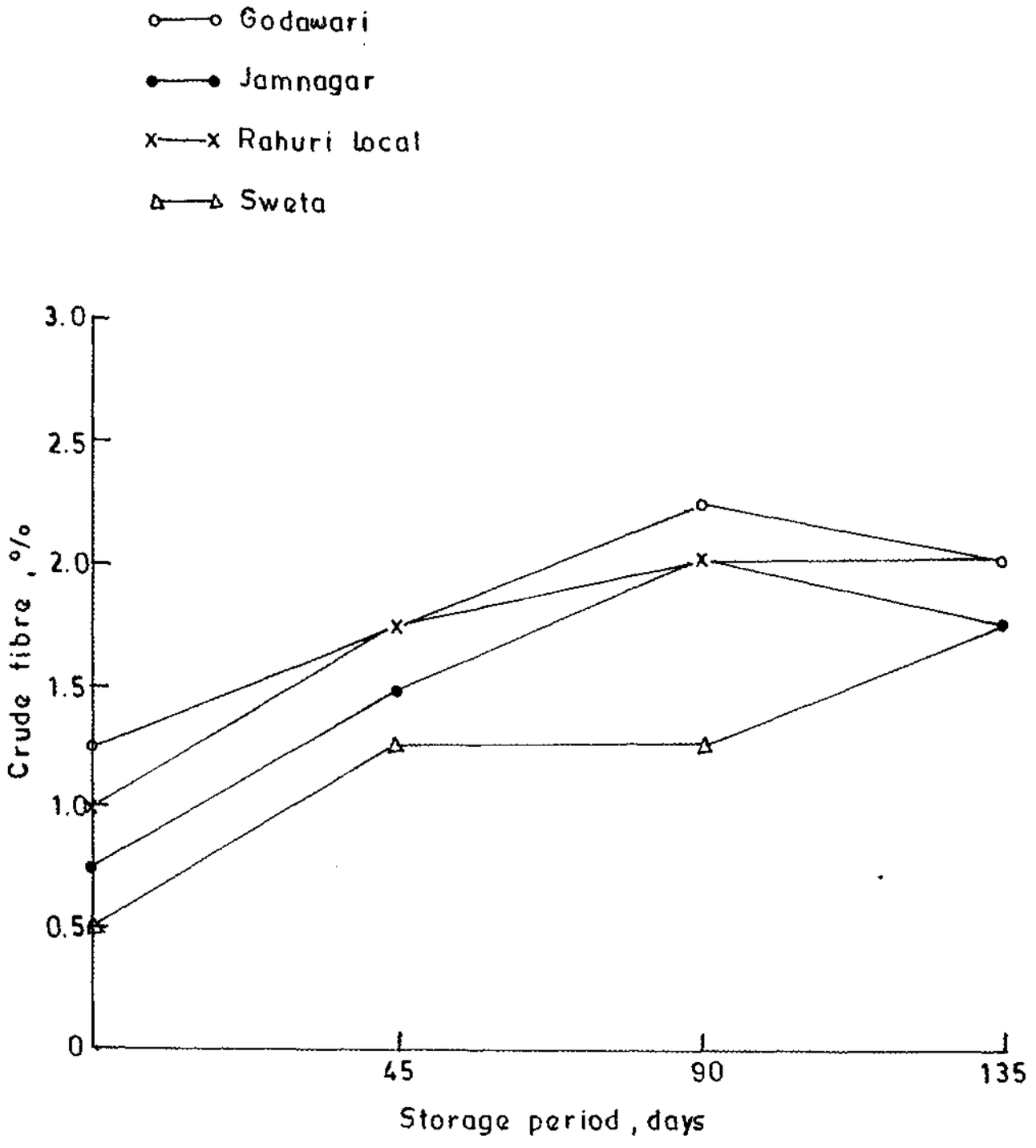
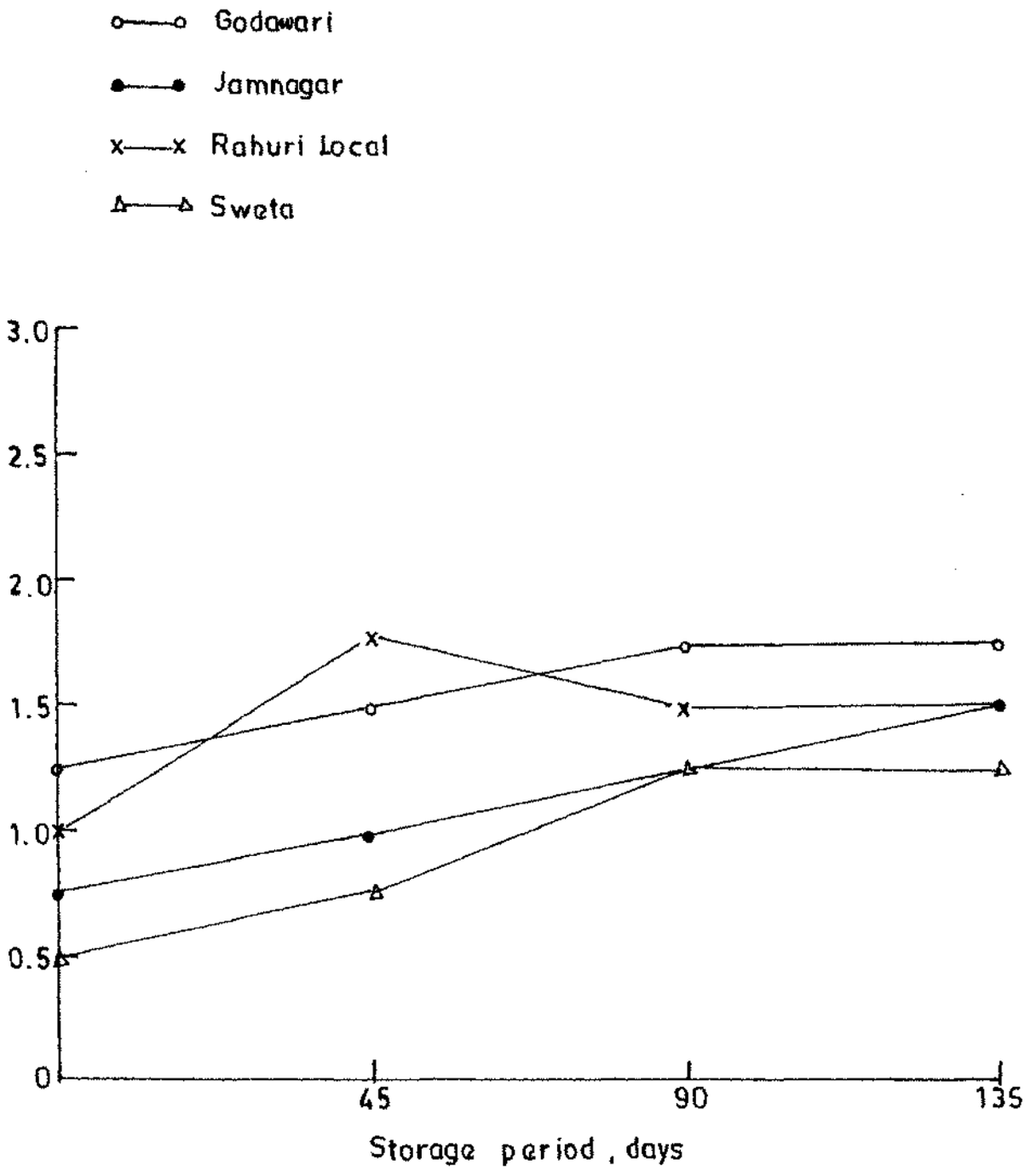



Fig. 9 Effect of storage on crude fibre content in the bulbs of four garlic cultivars stored with tops by hanging in bundles.




) Effect of storage on crude fibre content in the bulbs of four garlic cultivars stored with tops on the ground in bundles.

fibre in the diet is not to supply energy but to give bulk and thus to provide material for certain regulatory processes such as elimination of waste from the human intestines.

Freshly cured bulbs of garlic cultivars of Godawari, Jamnagar, Rahuri Local and Sweta contained 1.25%, 0.75%, 1% and 0.5% crude fibre content, respectively. The changes in crude fibre content in the bulbs of garlic during storage by two different methods is given in Table 6 and Fig. 9 and 10. The Table further shows that the crude fibre content in the garlic bulbs increased gradually during storage. It is also observed that the bulbs of garlic stored by hanging method have more crude fibre content than the bulbs stored in bundles on the ground. Comparative study as shown in Fig. 9 and 10 indicates that the Godawari cultivar has the highest crude fibre content and Sweta the lowest among the cultivars under study.

Various reports on the analysis of garlic (dry) also indicate 0.8% crude fibre (Roychoudhary, 1963; Pruthi, 1979). The content of crude fibre in dehydrated garlic powder is, however, 1.90% (Pruthi, 1979).

## 4.6 Carbohydrates

The changes in carbohydrate content in garlic bulbs, as measured by difference, during storage by two different storage methods are given in Table 7. The results reveal that the carbohydrate content in garlic cultivars did not change appreciably during storage. It was observed that the carbohydrate content in the bulbs of garlic was more in bundles hanged than those stored on the ground.

The data further indicate the comparative efficacy of two storage methods on the behaviour of four garlic cultivars in their carbohydrate contents. It is seen that carbohydrate content is more in Godawari cultivar and less in the Sweta cultivar.

Various studies have revealed that the storage of garlic has only a little effect on dry weight content although the relative proportion of reducing and nonreducing sugars vary greatly (Fenwick and Hanley, 1990).

As reported by Darbyshire and Henzy (1978), who examined bulbs of cv. Golden Brown Lockyer stored at 4, 15, 25 and 37°C for 12 weeks, sucrose, glucose and fructose contents increased

**Table 7. Effect of storage methods on carbohydrate content in four garlic cultivars**

| Sr. No. | Method of storage | Cultivars | Storage period, days | | | |
|---|---|---|---|---|---|---|
| | | | 0 | 45 | 90 | 135 |
| | | | Carbohydrate, % | | | |
| 1. | Garlic bundles stored by hanging | Godawari | 29.89 | 29.36 | 28.36 | 29.81 |
| | | Jamnagar | 28.40 | 27.82 | 27.95 | 28.63 |
| | | Rahuri L | 30.33 | 29.12 | 28.60 | 29.76 |
| | | Sweta | 31.47 | 28.58 | 29.62 | 29.56 |
| 2. | Garlic bundles stored on ground | Godawari | 31.47 | 31.47 | 28.18 | 29.13 |
| | | Jamnagar | 28.40 | 28.75 | 29.05 | 28.52 |
| | | Rahuri L | 30.33 | 32.32 | 31.82 | 30.77 |
| | | Sweta | 29.90 | 27.63 | 30.34 | 29.57 |
| S.E. for cultivars | | | 0.230 | 0.620 | 0.290 | 0.304 |
| C.D. at 5% | | | 0.700 | 1.800 | 0.870 | 0.911 |
| S.E. for storage | | | 0.166 | 0.440 | 0.200 | 0.214 |
| C.D. at 5% | | | 0.490 | 1.330 | 0.610 | 0.644 |
| S.E. for Int. ± | | | 0.330 | 0.880 | 0.410 | 0.420 |
| C.D. at 5% | | | 0.990 | 2.660 | 1.210 | 1.280 |

from outer to inner leaf bases with absolute concentration increasing with rising temperature.

Karmarkar and Joshi (1941) reported that storage of onions for 5 months at 0°C led to increase in total sugar, especially, reducing sugar contents. Storage at 35°C, however, caused decreases in both.

The total sugar content as well as the ratio of sucrose to monosaccharides of onion bulbs has been reported to be positively correlated with the keeping quality of the onion during storage (Butarin, 1958). Chang (1981) also noted that the lower content of reducing sugars was associated with the improved storage ability of onion bulbs.

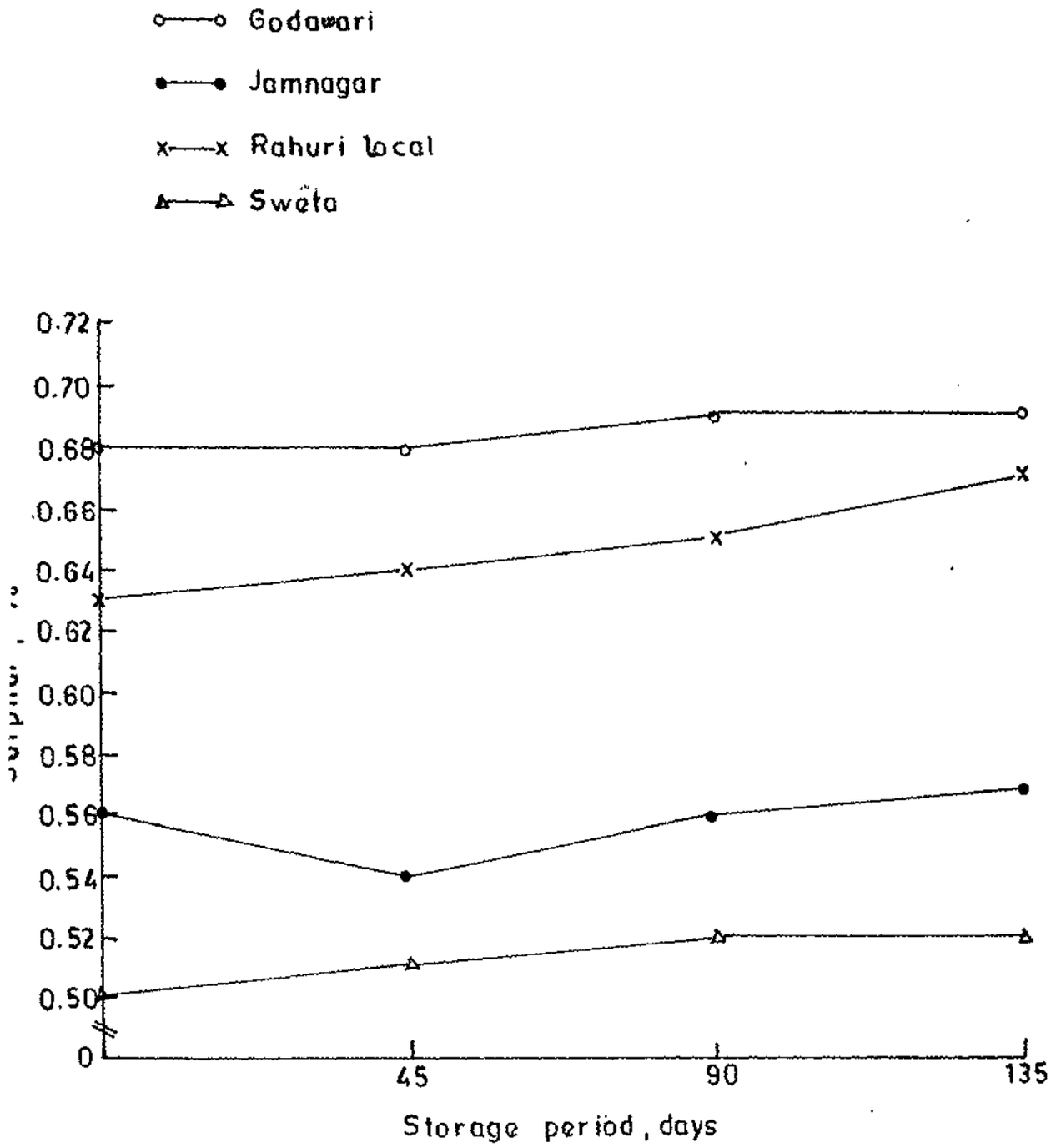
## 4.7 Total sulphur

The changes in the total sulphur content in the bulbs of garlic during storage by two different methods of storage is given in Table 8 and Fig. 11 and 12. There is a slight increase in total sulphur content during storage.

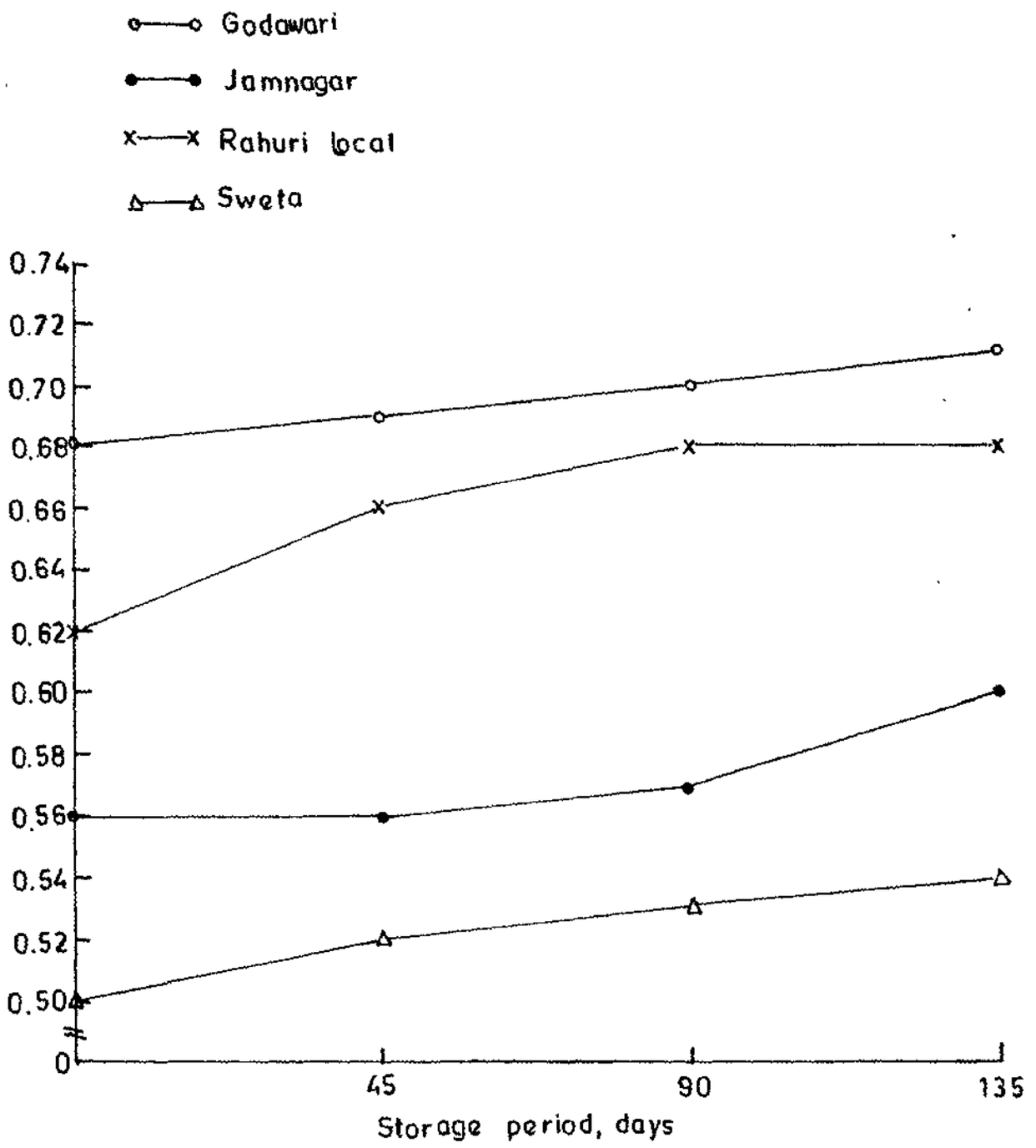
Comparison of the data from the Figures show that Godawari cultivar has more sulphur content than all other cultivars while Sweta has the least. The results further

**Table 8. Effect of storage methods on total sulphur content in four garlic cultivars**

| Sr. No. | Method of storage | Cultivars | Storage period, days | | | |
|---|---|---|---|---|---|---|
| | | | 0 | 45 | 90 | 135 |
| | | | Sulphur, % | | | |
| 1. | Garlic bundles stored by hanging | Godawari | 0.68 | 0.68 | 0.69 | 0.69 |
| | | Jamnagar | 0.56 | 0.54 | 0.56 | 0.57 |
| | | Rahuri L | 0.63 | 0.64 | 0.65 | 0.67 |
| | | Sweta | 0.49 | 0.51 | 0.52 | 0.52 |
| 2. | Garlic bundles stored on ground | Godawari | 0.68 | 0.69 | 0.70 | 0.71 |
| | | Jamnagar | 0.56 | 0.56 | 0.57 | 0.60 |
| | | Rahuri L | 0.63 | 0.67 | 0.68 | 0.68 |
| | | Sweta | 0.49 | 0.52 | 0.53 | 0.54 |
| S.E. for cultivars | | | 0.006 | 0.005 | 0.006 | 0.008 |
| C.D. at 5% | | | 0.018 | 0.017 | 0.022 | 0.024 |
| S.E. for storage | | | 0.001 | 0.004 | 0.004 | 0.005 |
| C.D. at 5% | | | 0.012 | 0.012 | 0.014 | 0.017 |
| S.E. for Int. ± | | | 0.006 | 0.008 | 0.009 | 0.011 |
| C.D. at 5% | | | 0.025 | 0.025 | 0.029 | 0.035 |




1. 11 Effect of storage on sulphur content in the bulbs of four garlic cultivars stored with tops by hanging in bundles.




1. 12 Effect of storage on sulphur content in the bulbs of four garlic cultivars stored with tops on the ground in bundles

indicate that sulphur content is less in garlic cultivars stored with tops by hanging than in garlic cultivars stored with tops on ground.

There are reports by researchers that there is a positive correlation between the sulphur content and pungency of the garlic cultivars (Kwon and Yoon, 1985). The characteristic odour of garlic is due to the volatile oil which consists of a large number of sulphur compounds like sulphides, disulphides, trisulphides, etc. (Shankarnarayana et al., 1981).

The pungency of the onion has been shown to be closely related to the keeping quality (Gilbert et al., 1963). Levels of sulphur components in garlic depend greatly upon exogenous sulphate fertilization and also upon the plant part examined as reported by Granroth (1970).

Pungency in onions, present due to a number of sulphur-containing compounds, releases the volatile flavour components when the onion tissue is damaged. The enzyme present in the vacuole of the cells then hydrolyses the alkyl or alkenyl cysteine sulphoxides which are held in the

cytoplasm and various sulphides and higher sulphides are formed which constitute the typical onion flavours (Fenwick and Hanley, 1990). Freeman and Whenham (1976) found that onion pungency increased for the first 190 days of storage and then declined with the onset of sprouting. The report by Smittle (1988) indicated that onion pungency increased during storage while total sugar content decreased.

# Summary and Conclusion

# 5. SUMMARY AND CONCLUSIONS

An experiment was conducted to study the effect of two storage methods on changes in the chemical composition of garlic bulbs of four cultivars stored upto 135 days after April harvest of 1995 at ambient temperature in the Department of Biochemistry, Mahatma Phule Krishi Vidyapeeth, Rahuri. The cultivars selected for this study were : Godawari, Jamnagar, Rahuri Local and Sweta. The results obtained in the present investigation are briefly summarized as follows :

5.1. The moisture content in garlic bulbs of all the four cultivars decreased steadily during the storage period of 135 days, from 58.70% to 56.75% in Godawari, from 62.80% to 58.55% in Jamnagar, from 59.70% to 57.30% in Rahuri Local and from 63.10% to 59.40% in Sweta cultivar of garlic in hanging method. However, when stored on ground it decreased from 58.70% to 58.20% in Godawari, from 62.80% to 60.10% in Jamnagar, from 59.70% to 56.00% in Rahuri Local and from 63.10% to 59.90% in Sweta cultivar of garlic. The results indicated that there was a greater moisture loss in the bulbs subjected to hanging method of storage than in the bulbs stored in bundles on the ground because of free aeration

5.2 The crude protein content in garlic bulbs of all the four cultivars increased gradually during storage, from 6.57 to 8.79% in Godawari, from 6.12 to 8.33% in Jamnagar, from 7.44% to 8.33% in Rahuri Local and from 4.82% to 6.36% in Sweta cultivars of garlic bulbs in hanging method. The increase was from 6.57 to 8.33% in Godawari, from 6.12 to 7.44% in Jamnagar, from 7.44 to 7.89% in Rahuri Local from 4.82 to 6.58% in Sweta garlic cultivars when stored on ground. Thus the protein content of the bulbs of garlic was higher in hanging method of storage than in the bulbs stored on the ground in bundles.

5.3 The crude fat content in the garlic bulbs of all the four cultivars decreased steadily during the storage period of 135 days, from 0.65 to 0.35% in Godawari, from 0.65 to 0.40% in Jamnagar, from 0.60 to 0.40 in Rahuri Local and from 0.55 to 0.35% in Sweta cultivars of garlic when stored by hanging method. The decrease was from 0.65 to 0.45% in Godawari, from 0.65 to 0.35% in Jamnagar, from 0.60 to 0.30% in Rahuri Local and 0.55 to 0.35% in Sweta cultivars of garlic when stored on ground. There was a greater crude fat loss in the bulbs stored by hanging method than in the bulbs stored in bundles on the ground.

5.4 The ash content increased slightly in the garlic bulbs of all the four cultivars when stored upto 135 days of storage, from 1.50 to 2.30% in Godawari, from 1.30 to 2.33% in Jamnagar, from 1.30 to 2.20 in Rahuri Local and from 1.10 to 1.80 in Sweta cultivars of garlic when stored by hanging method. However, when stored on the ground, the ash content increased from 1.50 to 2.30% in Godawari, from 1.30 to 2.16% in Jamnagar, from 1.20 to 2.20% in Rahuri Local and from 1.10 to 1.90% in Sweta cultivar of garlic. The increase in ash content in the bulbs of garlic was of the same magnitude for both the methods of storage.

5.5 The crude fibre content of garlic bulbs of all the four cultivars increased during storage. The increase was more in the bulbs of garlic when stored by hanging method than those stored on the ground, and it was from 1.25 to 2.00% in Godawari, from 0.75 to 1.75% in Jamnagar, from 1.00 to 2.00% in Rahuri Local and from 0.50 to 1.75% in Sweta cultivar of garlic in hanging method. For the bulbs of garlic when stored on ground, the increase was from 1.25 to 1.75% in Godawari, from 0.75 to 1.50 in Jamnagar, from 1.00 to 1.50% in Rahuri Local and from 0.50 to 1.25% in Sweta cultivar of galic.

5.6 The results further revealed that the carbohydrate content in garlic cultivars did not change significantly during storage. At the end of 135 days of storage, carbohydrate content was more in the bulbs stored by hanging method than in the bulbs stored on ground in bundles.

5.7 The sulphur content in garlic bulbs, however, increased during the storage period upto 135 days. The increase was more in the bulbs stored on the ground than those stored by hanging method. The increase was from 0.68 to 0.69% in Godawari, from 0.56 to 0.59% in Jamnagar, from 0.63 to 0 67% in Rahuri Local and from 0.49 to 0.52% in Sweta cultivar of garlic when stored by hanging method. For the bulbs of garlic when stored on ground, the increase was from 0.68 to 0.71% in Godawari, from 0.56 to 0.60% in Jamnagar, from 0.63 to 0.68% in Rahuri Local and from 0.49 to 0.59% in Sweta cultivar of garlic.

Based on these results it can be concluded that the garlic cultivars under investigation can be stored better at the ambient temperature with tops by hanging in a well ventilated room than with the tops on ground in bundles.

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* Originals not seen.

# Vita

# 8. V I T A

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**KAKASAHEB MAHADEO MORE**

A candidate for the degree

of

**MASTER OF SCIENCE (AGRICULTURE)**

in

1996.


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| | | |
|---|---|---|
| **Title of the thesis** | : | "INVESTIGATIONS ON THE CHEMICAL COMPOSITION IN BULBS OF FOUR GARLIC CULTIVARS AS INFLUENCED BY TWO STORAGE METHODS". |
| **Major field** | : | Agricultural Biochemistry |
| **Biographical information Personal data** | : | Born at Rashin, Tal. Karjat, Dist. Ahmednagar (Maharashtra) on September 5, 1970. Son of Shri Mahadeo Chandrasen More of Autewadi, Tal. Karjat, Dist Ahmednagar. |
| **- Educational** | : | Attended secondary and higher secondary schooling from National Model School and Fergusson College, Pune, respectively. Received the Bachelor of Science (Agriculture) degree from the college of Agriculture, Kolhapur, a consituent college of the MPKV, Rahuri. |

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# Appendix

# APPENDIX

Weather record during the period of experimentation

| Month | Days | Temperature, °C | | Humidity, % | | Wind velecity, km/hr | Rainfall, mm | Evapo-ration, mm |
|---|---|---|---|---|---|---|---|---|
| | | max. | min. | max. | min. | | | |
| April, 1995 | 1 | 34.5 | 13.7 | 61.0 | 35.0 | 3.8 | 0.0 | 8.4 |
| | 2 | 35.5 | 16.4 | 73.0 | 22.0 | 5.0 | 0.0 | 8.5 |
| | 3 | 34.2 | 16.0 | 71.0 | 18.0 | 2.9 | 0.0 | 9.2 |
| | 4 | 37.2 | 17.6 | 45.0 | 27.0 | 3.0 | 0.0 | 9.5 |
| | 5 | 38.2 | 16.4 | 54.0 | 15.0 | 4.5 | 0.0 | 9.8 |
| | 6 | 37.2 | 15.4 | 46.0 | 15.0 | 3.0 | 0.0 | 11.7 |
| | 7 | 38.0 | 15.4 | 48.0 | 16.0 | 3.7 | 0.0 | 10.0 |
| | 8 | 37.7 | 14.8 | 54.0 | 17.0 | 3.1 | 0.0 | 10.1 |
| | 9 | 36.9 | 14.5 | 56.0 | 20.0 | 4.1 | 0.0 | 10.9 |
| | 10 | 36.0 | 14.7 | 64.0 | 30.0 | 4.2 | 0.0 | 10.8 |
| | 11 | 36.7 | 14.7 | 72.0 | 23.0 | 4.0 | 0.0 | 8.8 |
| | 12 | 37.0 | 18.8 | 70.0 | 27.0 | 4.4 | 0.0 | 9.6 |
| | 13 | 37.8 | 19.0 | 50.0 | 27.0 | 4.0 | 0.0 | 10.0 |
| | 14 | 37.6 | 16.2 | 70.0 | 14.0 | 4.5 | 0.0 | 11.6 |
| | 15 | 37.4 | 13.8 | 64.0 | 16.0 | 5.4 | 0.0 | 10.6 |
| | 16 | 37.0 | 15.4 | 62.0 | 16.0 | 4.4 | 0.0 | 8.0 |

Appendix Contd...

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 17 | 36.8 | 16.6 | 61.0 | 21.0 | 3.3 | 0.0 | 9.6 |
| | 18 | 35.9 | 16.5 | 64.0 | 23.0 | 3.2 | 0.0 | 10.0 |
| | 19 | 36.7 | 19.4 | 85.0 | 29.0 | 5.2 | 0.0 | 10.4 |
| | 20 | 37.4 | 19.4 | 90.0 | 31.0 | 3.5 | 34.5 | 9.0 |
| | 21 | 35.0 | 21.1 | 76.0 | 26.0 | 2.2 | 0.0 | 10.4 |
| | 22 | 36.8 | 18.8 | 82.0 | 26.0 | 2.8 | 0.0 | 9.4 |
| | 23 | 38.0 | 20.1 | 63.0 | 15.0 | 3.6 | 0.0 | 10.6 |
| | 24 | 38.4 | 18.5 | 52.0 | 16.0 | 3.1 | 0.0 | 10.2 |
| | 25 | 38.5 | 19.7 | 54.0 | 18.0 | 4.8 | 0.0 | 11.4 |
| | 26 | 39.0 | 19.7 | 45.0 | 18.0 | 3.9 | 0.0 | 11.2 |
| | 27 | 39.7 | 22.2 | 58.0 | 25.0 | 8.0 | 0.6 | 10.6 |
| | 28 | 37.6 | 24.6 | 76.0 | 25.0 | 5.6 | 0.0 | 10.9 |
| | 29 | 38.0 | 26.0 | 56.0 | 39.0 | 5.6 | 0.0 | 9.0 |
| | 30 | 37.1 | 24.0 | 66.0 | 28.0 | 3.3 | 0.0 | 8.4 |
| May, 95 | 1 | 38.0 | 21.0 | 66.0 | 28.0 | 3.3 | 0.0 | 9.8 |
| | 2 | 37.7 | 21.4 | 69.0 | 28.0 | 6.0 | 0.0 | 10.5 |
| | 3 | 35.4 | 22.4 | 72.0 | 32.0 | 7.5 | 0.0 | 9.5 |
| | 4 | 37.9 | 23.3 | 71.0 | 27.0 | 7.8 | 0.0 | 10.9 |
| | 5 | 37.8 | 25.2 | 68.0 | 24.0 | 6.4 | 0.0 | 10.2 |
| | 6 | 39.0 | 21.2 | 64.0 | 19.0 | 3.9 | 0.0 | 10.6 |

Appendix Contd...

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 7 | 39.5 | 22.0 | 61.0 | 24.0 | 5.5 | 0.0 | 10.5 |
| 8 | 35.4 | 23.0 | 64.0 | 34.0 | 11.3 | 0.0 | 13.6. |
| 9 | 36.8 | 23.0 | 82.0 | 34.0 | 3.7 | 0.0 | 9.0 |
| 10 | 38.4 | 23.5 | 78.0 | 32.0 | 4.3 | 1.5 | 10.8 |
| 11 | 37.0 | 26.0 | 63.0 | 33.0 | 8.0 | 0.0 | 11.1 |
| 12 | 37.4 | 24.6 | 69.0 | 33.0 | 4.3 | 0.0 | 9.7 |
| 13 | 38.2 | 25.2 | 72.0 | 36.0 | 6.1 | 0.0 | 10.0 |
| 14 | 38.1 | 24.6 | 70.0 | 27.0 | 10.1 | 0.0 | 9.6 |
| 15 | 37.2 | 24.0 | 74.0 | 28.0 | 11.0 | 0.0 | 11.4 |
| 16 | 37.2 | 24.0 | 77.0 | 29.0 | 14.4 | 0.0 | 11.8 |
| 17 | 37.2 | 21.2 | 78.0 | 25.0 | 12.3 | 0.0 | 14.1 |
| 18 | 36.2 | 21.2 | 79.0 | 48.0 | 12.3 | 0.0 | 10.0 |
| 19 | 36.2 | 21.0 | 83.0 | 24.0 | 11.0 | 0.0 | 11.7 |
| 20 | 36.4 | 19.4 | 77.0 | 26.0 | 8.1 | 0.0 | 12.6 |
| 21 | 37.6 | 19.0 | 80.0 | 24.0 | 6.0 | 0.0 | 11.7 |
| 22 | 36.0 | 19.2 | 74.0 | 26.0 | 6.2 | 0.0 | 11.3 |
| 23 | 36.7 | 18.5 | 73.0 | 26.0 | 6.5 | 0.0 | 10.0 |
| 24 | 36.2 | 21.7 | 72.0 | 26.0 | 5.5 | 0.0 | 11.5 |
| 25 | 37.4 | 24.7 | 69.0 | 27.0 | 6.0 | 0.0 | 11.4 |
| 26 | 38.0 | 24.7 | 85.0 | 33.0 | 8.5 | 0.0 | 9.8 |

Appendix Contd...

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 27 | 37.5 | 22.2 | 81.0 | 29.0 | 8.8 | 0.0 | 10.3 |
| | 28 | 38.0 | 23.4 | 85.0 | 17.0 | 2.7 | 6.5 | 10.9 |
| | 29 | 41.0 | 28.2 | 72.0 | 27.0 | 4.5 | 0.0 | 9.6 |
| | 30 | 37.8 | 26.6 | 72.0 | 23.0 | 7.6 | 0.0 | 11.0 |
| | 31 | 39.2 | 26.5 | 74.0 | 26.0 | 9.5 | 0.0 | 10.8 |
| June, 95 | 1 | 40.6 | 23.4 | 51.0 | 21.0 | 10.1 | 0.0 | 14.4 |
| | 2 | 41.2 | 26.5 | 59.0 | 16.0 | 11.0 | 0.0 | 14.5 |
| | 3 | 42.0 | 23.5 | 55.0 | 27.0 | 10.5 | 0.0 | 15.0 |
| | 4 | 41.4 | 21.0 | 49.0 | 26.0 | 9.7 | 0.0 | 14.0 |
| | 5 | 40.7 | 21.5 | 67.0 | 35.0 | 10.6 | 0.0 | 14.6 |
| | 6 | 39.4 | 24.6 | 70.0 | 37.0 | 12.4 | 0.0 | 14.2 |
| | 7 | 38.2 | 23.7 | 85.0 | 30.0 | 12.2 | 0.0 | 14.6 |
| | 8 | 38.6 | 22.7 | 76.0 | 30.0 | 12.2 | 0.0 | 13.2 |
| | 9 | 38.0 | 22.4 | 85.0 | 26.0 | 10.6 | 0.0 | 12.5 |
| | 10 | 36.0 | 24.0 | 71.0 | 33.0 | 12.3 | 0.0 | 14.1 |
| | 11 | 36.0 | 22.5 | 71.0 | 39.0 | 10.2 | 0.0 | 15.6 |
| | 12 | 35.5 | 23.4 | 71.0 | 36.0 | 10.4 | 0.0 | 13.1 |
| | 13 | 37.4 | 24.4 | 84.0 | 41.0 | 5.5 | 0.0 | 6.9 |
| | 14 | 38.0 | 23.4 | 86.0 | 42.0 | 4.8 | 2.3 | 7.7 |
| | 15 | 37.8 | 24.7 | 83.0 | 46.0 | 10.6 | 0.0 | 10.0 |

Appendix Contd...

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 16 | 36.6 | 24.2 | 79.0 | 35.0 | 9.0 | 0.0 | 10.8 |
| | 17 | 36.7 | 25.7 | 75.0 | 42.0 | 7.4 | 0.0 | 9.0 |
| | 18 | 34.4 | 24.8 | 71.0 | 37.0 | 6.4 | 0.0 | 11.4 |
| | 19 | 35.7 | 25.2 | 79.0 | 39.0 | 16.5 | 0.0 | 11.0 |
| | 20 | 36.0 | 25.2 | 73.0 | 44.0 | 12.4 | 0.0 | 10.7 |
| | 21 | 34.0 | 24.4 | 78.0 | 54.0 | 8.1 | 0.0 | 10.0 |
| | 22 | 33.3 | 23.0 | 73.0 | 43.0 | 5.6 | 0.0 | 6.2 |
| | 23 | 35.7 | 23.6 | 74.0 | 68.0 | 9.8 | 0.0 | 10.6 |
| | 24 | 34.2 | 22.2 | 85.0 | 54.0 | 5.1 | 50.0 | 8.0 |
| | 25 | 31.1 | 22.8 | 84.0 | 81.0 | 5.4 | 0.0 | 7.2 |
| | 26 | 36.0 | 23.6 | 81.0 | 74.0 | 6.5 | 3.0 | 65.0 |
| | 27 | 30.6 | 23.5 | 87.0 | 79.0 | 6.5 | 2.6 | 3.6 |
| | 28 | 28.0 | 23.5 | 89.0 | 58.0 | 3.1 | 0.0 | 2.2 |
| | 29 | 31.6 | 24.5 | 82.0 | 46.0 | 7.2 | 0.0 | 6.0 |
| | 30 | 31.5 | 20.1 | 92.0 | 68.0 | 6.4 | 0.5 | 6.2 |
| July, 95 | 1 | 29.2 | 24.5 | 76.0 | 52.0 | 11.4 | 1.0 | 5.4 |
| | 2 | 31.6 | 23.7 | 90.0 | 52.0 | 11.1 | 0.0 | 6.0 |
| | 3 | 32.2 | 23.7 | 86.0 | 41.0 | 11.4 | 0.0 | 8.4 |
| | 4 | 34.0 | 22.2 | 75.0 | 40.0 | 11.5 | 0.0 | 11.8 |
| | 5 | 34.8 | 24.0 | 81.0 | 30.0 | 10.3 | 0.0 | 8.5 |

Appendix Contd...

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 6 | 32.6 | 23.2 | 87.0 | 46.0 | 6.9 | 6.8 | 8.6 |
| 7 | 34.4 | 24.2 | 79.0 | 41.0 | 4.3 | 0.0 | 6.6. |
| 8 | 35.2 | 23.4 | 83.0 | 50.0 | 4.9 | 4.8 | 4.8 |
| 9 | 33.8 | 24.0 | 85.0 | 43.0 | 3.9 | 0.0 | 6.6 |
| 10 | 35.0 | 22.0 | 89.0 | 55.0 | 5.6 | 51.7 | 7.5 |
| 11 | 33.2 | 23.5 | 80.0 | 61.0 | 6.1 | 0.0 | 6.0 |
| 12 | 30.2 | 23.4 | 85.0 | 56.0 | 8.8 | 0.0 | 4.5 |
| 13 | 31.2 | 23.6 | 85.0 | 63.0 | 11.5 | 0.0 | 5.0 |
| 14 | 31.8 | 24.0 | 86.0 | 65.0 | 10.7 | 0.0 | 5.2 |
| 15 | 29.2 | 23.4 | 81.0 | 27.0 | 7.8 | 0.6 | 2.4 |
| 16 | 29.2 | 23.7 | 87.0 | 64.0 | 10.9 | 0.4 | 3.4 |
| 17 | 30.5 | 23.0 | 79.0 | 60.0 | 12.2 | 0.2 | 5.0 |
| 18 | 30.0 | 23.4 | 74.0 | 84.0 | 12.3 | 1.8 | 4.8 |
| 19 | 26.7 | 23.0 | 83.0 | 73.0 | 12.8 | 1.6 | 3.4 |
| 20 | 26.4 | 22.5 | 85.0 | 69.0 | 10.7 | 1.2 | 3.2 |
| 21 | 27.2 | 23.2 | 81.0 | 67.0 | 10.3 | 2.7 | 3.3 |
| 22 | 27.8 | 22.2 | 82.0 | 74.0 | 7.4 | 0.0 | 3.5 |
| 23 | 27.0 | 23.0 | 79.0 | 61.0 | 6.7 | 0.0 | 4.2 |
| 24 | 30.0 | 22.2 | 81.0 | 76.0 | 8.5 | 2.0 | 4.0 |
| 25 | 27.0 | 23.2 | 90.0 | 77.0 | 7.0 | 0.8 | 3.2 |

Appendix Contd...

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 26 | 29.6 | 22.2 | 78.0 | 64.0 | 8.1 | 0.4 | 3.7 |
| | 27 | 30.0 | 22.2 | 79.0 | 57.0 | 8.1 | 0.4 | 3.0 |
| | 28 | 31.0 | 23.0 | 78.0 | 54.0 | 2.8 | 0.2 | 5.6 |
| | 29 | 32.0 | 22.6 | 74.0 | 53.0 | 7.7 | 0.0 | 6.4 |
| | 30 | 33.0 | 22.0 | 84.0 | 72.0 | 9.4 | 0.8 | 5.5 |
| | 31 | 30.0 | 22.2 | 86.0 | 47.0 | 2.7 | 1.2 | 3.2 |
| Aug., 95 | 1 | 33.0 | 23.2 | 78.0 | 58.0 | 8.5 | 0.0 | 6.0 |
| | 2 | 31.1 | 23.5 | 86.0 | 69.0 | 11.6 | 0.0 | 5.5 |
| | 3 | 30.7 | 23.5 | 87.0 | 64.0 | 10.3 | 0.0 | 6.2 |
| | 4 | 28.6 | 23.5 | 81.0 | 54.0 | 8.3 | 0.0 | 4.0 |
| | 5 | 31.4 | 23.2 | 81.0 | 72.0 | 9.6 | 0.0 | 4.4 |
| | 6 | 31.6 | 22.5 | 78.0 | 53.0 | 9.3 | 0.0 | 6.2 |
| | 7 | 32.2 | 23.8 | 76.0 | 62.0 | 12.9 | 0.0 | 8.2 |
| | 8 | 30.0 | 24.0 | 84.0 | 53.0 | 10.8 | 0.0 | 6.0 |
| | 9 | 30.7 | 23.6 | 78.0 | 54.0 | 10.1 | 0.0 | 6.1 |
| | 10 | 31.5 | 20.5 | 71.0 | 43.0 | 7.3 | 0.0 | 6.1 |
| | 11 | 33.5 | 22.1 | 75.0 | 46.0 | 2.8 | 0.0 | 6.2 |
| | 12 | 34.2 | 22.0 | 89.0 | 56.0 | 3.1 | 15.0 | 6.0 |
| | 13 | 30.1 | 26.0 | 71.0 | 50.0 | 6.3 | 0.0 | 4.9 |