STUDIES ON THE EFFECTS OF DIFFERENT SUBSTRATES ON YIELD AND QUALITY OF MUSHROOM
(Sp. *Pleurotus sajor-caju*)

By

ANAND BABURAO JADHAV

Univ Enrol. No. 93176

A thesis submitted to the

MAHATAMA PHULE KRISHI VIDYAPEETH
RAHURI, DIST. AHMEDNAGAR
(MAHARASHTRA)

in

the partial fulfilment of the requirement for the degree

of

MASTER OF SCIENCE (Agriculture)

in

AGRICULTURAL CHEMISTRY

AGRICULTURAL CHEMISTRY AND SOIL SCIENCE DEPARTMENT
COLLEGE OF AGRICULTURE, PUNE - 411 005

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CANDIDATE'S DECLARATION

I hereby declare that the dissertation entitled, **"STUDIES ON THE EFFECTS OF DIFFERENT SUBSTRATES ON YIELD AND QUALITY OF MUSHROOM (Sp. *Pleurotus sajor-caju*)"** or any part of the dissertation has not been previously submitted by me or any other person to any other University or Institute for a degree or diploma or published.

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Date : Jully 29, 1995

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This is to certify that the dissertation entitled, " **STUDIES ON THE EFFECTS OF DIFFERENT SUBSTRATES ON YIELD AND QUALITY OF MUSHROOM (Sp.** ***Pleurotus sajor-caju*** **)"** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri 413 722, Maharashtra State, India in fulfilment of the requirements for the degree of MASTER OF SCIENCE, (AGRICULTURE) in AGRICULTURAL CHEMISTRY, embodies the results of a piece of bona fide research work carried out by **Mr. Anand Baburao Jadhav,** under my guidance and supervision and that no part of the dissertation has been submitted for any other degree or diploma or published.

The assistance and help rendered during the course of the investigation have been duly acknowledged.

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Place : Pune

Date : 29 JUL 1995

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Place : Pune

Date 10 JUL 1995

[Anand B. Jadhav]

CONTENTS

Page No.

CANDIDATE'S DECLARATION ii

CERTIFICATES : i) Research Guide iii

ii) Associate Dean iv

ACKNOWLEDGEMENTS v - vi

CONTENTS vii - x

LIST OF TABLES xi - xii

LIST OF FIGURES xiii - xiv

ABSTRACT xv - xvi

1. INTRODUCTION 01

2. REVIEW OF LITERATURE.................................. 07

2.1 Effects of Temperature and humidity on yield and quality of mushrooms................ 07

2.2 Chemical composition of substrates before to mushroom cultivation....................... 09

2.3 Effect of different substrates on yield of mushroom.................................. 11

2.4 Effect of different substrates on quality of mushroom................................. 15

2.5 Chemical composition of different spent substrate (after mushroom cultivation)........ 17

3. MATERIALS AND METHODS.............................. 21

3.1 Experimental site.............................. 21

3.2 Climatic conditions........................... 21

3.3 Mushroom culture.............................. 21

3.4 Preparation of master and commercial spawn.... 22

3.4.1. Master spawn........................ 22

3.4 2. Commercial spawn.................... 23

3.4 3. Experimental details................ 23

3.4.4. Substrates.......................... 26

3.5 Cultivation method............................ 26

3.5.1 Polythene bags...................... 26

3.5.2 Spawn............................... 27

3.5.3 Cultivation room.................... 27

3.5.4 Cultivation technique............... 27

3.6 Details of observations....................... 32

3.6.1 Pileus size......................... 32

3.6.2 Stipe length (cm)................... 32

3.6.3 Days required for first flush....... 33

3.6.4 Number of sporophore................ 33

3.6.5 Weight of sporophore................ 33

3.6.6 Yield................................ 33

3.6.7 Biological efficiency............... 33

3.7 Methods of chemical analysis.................. 33

3.7.1 Analysis of original straw and spent straw......................... 33

3.7.2 Analysis of fresh mushroom.......... 34

3.8 Statistical Analysis and interpretation of data.. 34

4. RESULTS AND DISCUSSION............................. 36

4.1. Effect of mushroom cultivation on chemical composition of different substrates........... 36

4.1.1 Moisture content.................... 36

4.1.2 Nitrogen content.................... 38

4.1.3 Crude protein content.............. 40

4.1.4 Organic carbon content.............. 42

4.1.5 C:N ratio.......................... 44

4.2 Mineral matter content........................ 46

4.2.1 Calcium content..................... 48

4.2.2 Phosphorous content................. 50

4.2.3 pH................................. 52

4.3 Effect of different substrates on stipe length, pileus size, and days required for first flush.................................. 54

4.3.1 Stipe length........................ 54

4.3.2 Pileus size......................... 54

4.3.3 Days required for first flush....... 56

4.4 Effect of different substrates on number of sporophore, weight of sporophore, yield and biological efficiency of mushroom............. 56

4.4.1 Number of sporophore................ 56

4.4.2 Weight of sporophore................ 58

4.4.3 Yield and biological efficiency..... 58

4.5 Effect of different substrates on proximate composition of mushroom (*P. sajor-caju*)....... 59

4.5.1 Moisture........................... 59

4.5.2 Dry matter......................... 61

4.5.3 Crude Protein...................... 61

4.5.4 Carbohydrates...................... 62

4.5.5 Fat................................ 63

4.5.6 Crude fibre........................ 64

4.5.7 Mineral matter..................... 64

4.6 Effect of different substrates on calcium, phosphorus and Iron content of mushroom (mg $100g^{-1}$) 65

4.6.1 Calcium 65

4.6.2 Phosphorus 67

4.6.3 Iron 68

4.7 Impact of different substrates on quality of mushroom 68

5. SUMMARY AND CONCLUSIONS 70

6. LITERATURE CITED 74

7. VITA 86

LIST OF TABLES

Table No.	Title	Page No.
1.	Details of Treatments..........................	24
2.	Operations carried out during cultivation of Mushroom..	25
3.	Relative humidity and temperature during cultivation of mushroom in the room.............	28
4.	Methods used for analysis of straw, spent straw and mushrooms..............................	35
4a.	Effect of mushroom cultivation on moisture content of different substrates.................	37
5.	Effect of mushroom cultivation on nitrogen content of different substrates.................	39
6.	Effect of mushroom cultivation on crude protein content different substrates............	41
7.	Effect of mushroom cultivation on organic carbon content of different substrates..........	43
8.	Effect of mushroom cultivation on C:N ratio of different substrates............................	45
9.	Effect of mushroom cultivation on mineral matter content of different substrates..........	47
10.	Effect of mushroom cultivation on calcium content of different substrates mg 100 g^{-1})......	49
11.	Effect of mushroom cultivation on phosphorus content of different substrates (mg $100g^{-1}$).....	51
12.	Effect of mushroom cultivation on pH of different substrates.............................	53
13.	Effect of different substrates on stipe length, pileus size and days required for first flush....................................	55
14.	Effect of different substrates on number of sporophore, weight of sporophore, yield and biological efficiency of mushroom...............	57

15.	Effect of different substrates on proximate composition of P. Sajor-caju (fresh weight basis)..	60
16.	Effect of different substrates on calcium phosphorous and iron content of Pleurotus sajor-caju (expressed in mg $100g^{-1}$.)............	66

LIST OF FIGURES

Figure	Title	Between Page
1.	Effect of mushroom cultivation on moisture content of different substrates.	37-38
2.	Effect of mushroom cultivation on nitrogen content of different substrates.	39-40
3.	Effect of mushroom cultivation on crude protein content of different substrates.	41-42
4.	Effect of mushroom cultivation on organic carbon content of different substrates.	43-44
5.	Effect of mushroom cultivation on C : N ratio of different substrates.	45-46
6.	Effect of mushroom cultivation on mineral matter content of different substrates.	47-48
7.	Effect of mushroom cultivation on Ca content of different substrates.	49-50
8.	Effect of mushroom cultivation on P content of different substrates.	51-52
9.	Effect of mushroom cultivation on pH of different substrates.	53-54
10.	Effect of different substrates on stipe length, pileus size and days required for first flush of mushroom.	55-56
11 A.	Effect different substrates on number and weight of sporophore of mushroom.	57-58
11 B.	Effect different substrates on yield and biological efficiency of mushroom.	57-58
12.	Effect different substrates on moisture content of mushroom.	60-61
12 A.	Effect different substrates on dry matter yield of mushroom.	60-61
12 B.	Effect different substrates on crude protein content of mushroom.	60-61

12 C.	Effect different substrates on carbohydrates content of mushroom.	60-61
12 D.	Effect different substrates on fat content of mushroom.	60-61
12 E.	Effect different substrates on crude fiber content of mushroom.	60-61
12 F.	Effect different substrates on mineral matter content of mushroom.	60-61
13.	Effect different substrates on Ca, P, Fe, content of mushroom.	67-68

ABSTRACT

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The present study was undertaken to find out the effects of different substrates on yield and quality of mushroom (Sp. *Pleurotus sajor-caju*) during the winter 1994, at All India Co-ordinated Mushroom Improvement Project, College of Agriculture, Pune.

The study revealed significant changes in the physico-chemical composition of the substrates due to mushroom cultivation. Nitrogen content of different substrates was found to be increased upto 3.14%. Under the cultivation of the mushroom the carbon content and C:N ratio of different substrates were reduced upto 6.8 per cent and 20.51, respectively. On the other hand the calcium and phosphorus contents of different substrates were increased.

The morphological and yield contributing characters of mushroom were observed significantly influenced by the different substrates. Increase in respect of number of sporophore, upto 178.3 bed^{-1} and average weight of sporophore of mushroom upto 5.1g was observed in cotton stalks and leaves. The highest stipe

length of mushroom 3.5 cm was seen in case of combination of soybean straw + wheat straw, however the highest pileus size of mushroom 29.40 cm^2 was noticed in *bajra* stalks and leaves.

The highest yield of mushroom was recorded in respect of cotton stalks and leaves (914.3 g^{-1} Kg of straw) followed by paddy straw (796.3 g^{-1} Kg of straw). On the other hand the groundnut creepers showed lowest yield of mushroom (257.7 g^{-1} Kg of straw). The quality of mushroom in respect of carbohydrate, fat, crude fibre, mineral matter were found significantly affected due to different substrates. The different substrates did not show much differences in crude protein content of mushroom.

The minerals viz. calcium, phosphorus and iron content of mushrooms were found significantly influenced due to different substrates tried.

It could be summerized that due to cultivation of oyster mushroom the concentration of minerals viz. nitrogen, phosphorus and calcium in spent straw was increased with the reduction in the C : N ratio thus, increased its suitability for use as a quality manure as well as feed stuff. Similarly the quality of mushroom grown on cotton stalks and leaves was found superior in respect of moisture, crude protein, crude fibre and iron content over rest of the substrates under study.

T-3266

Chapter Opener Page

INTRODUCTION

1. INTRODUCTION

India is an agricultural country with 80% population dependent on agriculture and lives in villages. Removal of poverty in the rural area is one of the most priorities before the planners. Poverty is lurking in India mostly in the villages because of unemployment, under employment and below sustaining levels of living. Because of poverty, the problem of malnutrition is quite acute and the country has almost the lowest per capita consumption of protein amongs the developing countries. This is due to decline in pulse production in recent years.

The food problems in our country are of varied kind. Many people in India suffer due to malnutrition especially because of protein deficiency. The meat and eggs are rich in protein but can not be included in diet by the vegetarian and too costly for the common man. Under these conditions all possible sources of protein production shall have to be exploited to solve the problem of protein hunger.

In view of this, mushroom industry is likely to bridge the gap between the requirement and the actual consumption of protein by Indian people and can save the country from malnutrition. Mushroom production does not demand much land, costly seeds, fertilizer, irrigation labour and other inputs as compared with crop production.

Less time consumption, no drudgery (laborious) in door or nearby space availability are the advantages of mushroom cultivation. According to the fossil record, mushrooms have existed since the lower cretaceous period (approximately 130

T-3266

million years ago), long before human beings evolved on this planet. It is probable that the earliest beginnings man has utilized mushrooms as a food and we also observe present day that animals consume mushrooms and truffles growing wild. In nature mushrooms are not only a source of food but also play an important role in recycling of carbon and other elements through the bio - degradation process.

The protein content of mushroom is twice as high in most vegetables and having good digestibility (Mow and Flegg, 1975). Mushrooms are also an excellent source of vitamins and minerals. The mineral content particularly calcium and phosphorus are remarkably higher in mushroom than in many fresh vegetables which again are extremly useful for the body building process. A lot of bio waste is being generated in rural areas and this waste could be utilized directly through mushroom cultivation converting them to protein rich palatable food. The mushrooms have the ability to transform nutritionally valueless waste into highly acceptable nutritious food. In addition, the mushroom cultivation is labour intensive and provides employment opportunities which is an important basic need of the country for meeting the requirement of growing population.

First time mushrooms were grown in France. Now most of Europ, USSR, Australia and United States of America are intense mushroom growers. China and Japan cultivate a special kind of wood flavoured mushrooms.

In India first successful attempt on the artificial cultivation of mushroom was made in 1943 at Coimbatore in Tamil

Nadu, when paddy straw was used for cultivation of mushrooms. Cultivation of white button mushroom (*Agaricus bisporus*) was initiated at Solan in Himachal Pradesh in 1961, when a scheme entitled "Development of mushroom cultivation in Himachal Pradesh" was undertaken at Solan by Government and ICAR, New Delhi.

Oyster mushroom cultivation were started in India in 1962 when *Pleurotus flabellatus* was cultivated on paddy straw by Bano and Shrivastava (1962). The earliest cultivation of *P. sajor caju* on tobacco pseudostem and paddy straw was done by Jandaik and Kapoor (1974).

There are more than 45,000 species of fungi known to science. Nearly 2,000 of these are considered edible. We also know about 100 species of mushrooms are accepted as an item of food of which only a dozen or two have so been commercially cultivated. The most important mushroom collected in India is gucchi (*Morchella* Spp.).

The total world production of mushroom in 1989-90 was 3.763 million tonns. United states of America tops the list for production of mushroom followed by China, France, Holland, England and Canada. China has emerged as a big producer and exporter of mushrooms particularly of *Pleurotus* and *Auricularia*. In India the mushroom production in 1992 was approximetly 12,000 tonnes and is expected to cross 25,000 tonnes by 1995. India exported 50 MT of dried mushroom and 1175 MT processed mushroom worth Rs. 1222.4 lakhs in 1991-92. The annual rate of increase over 5 years was about 19.3% but differed considerably between species productiqn of *Pleurotus* Spp. rose by 31 per cent.

The major mushroom producing states in India are Uttar Pradesh, Himachal Pradesh, Panjab, Tamil Nadu, Haryana etc. Production of mushroom in Maharashtra in 1992-93 is about 250 tonnes and is expected to cross 500 tonnes by 1994-95. Entrepreneurs and growers form Tamil Nadu, Karnataka, Kerala, Andhra Pradesh and Maharashtra have recently taken up large scale mushroom cultivation. The major mushroom producing centres in south India are Bangalore, Hyderabad, Pune, Munnar, Madras, Ootacamund and Coimbatore. Cost of mushroom production falls in the range of Rs.10-30/- per Kg. of fresh depending on *Pleurotus* or *Agaricus*. The product fetches after processing Rs.60-70/- in the international market.

The food value of mushroom lies between vegetable and animal food values. Most mushrooms are fair source of proteins and contain little amount of starch (Gopalan, 1989). Mushroom produce high quantity and quality protein from worthless agrowastes. The protein is superier to other plant protein and is rich in lysine which is an essential amino acid. Mushrooms are oldest single cell protein (SCP) foods of the man and are valued for their excellent flavour and usefulness in increasing palatability of other foods. Mushroom contain prevelant water content (~ 90%) in the fresh form. Mushrooms are also an excellant source of vitamins and minerals. The mineral content particularly calcium and phosphorus are remarkably higher in mushroom than in many fresh vegetables which again useful for the body building processes.

The mushroom processing is required to achieve storage, transport and trade over a course of time while, more and more research developments are occuring on the improvement of production technologies similar magnitude of scientific efforts for processing mushrooms are necessary to keep pace with the growing demands in the international market.

Oyster mushroom is one of the important mushroom cultivated in world. The temperature requirment of this mushroom (*Pleurotus sajor-caju*) ranges between 20-30^{0}C during entire cropping period which makes them an ideal species for cultivation in most part of the country having tropical and subtroplical climate.

In Maharashtra mushroom cultivation is newly started and there is wide scope in respect of environmental condition for cultivation.

Rumen microbial digestion of straws due to high lignification, low crude protein content can be imporved either by supplimenting with a concentrate mixture or by processing with cultivation of edible mushroom on these straws, is important since, it provides nutritious mushroom for human consumption. In India Delhi is the largest consumer of mushroom and the biggest trade centre for mushrooms.

Mushroom acts as a unique food for diabetic patients due to its low starch, fat and carbohydrate. However the information on the qualitative aspect due to different substrates is meagre. It is obvious that quality of the mushroom has to be mainly governed by the nature of the substrate. Straw with different nutrients and making it a good cattle feed. Therefore, considering the nutritional value and ability of mushroom to convert bio-waste into nutritional food and all beneficial aspects of mushroom cultivation the present investigation was planned to study the effect of different substrates on the yield and quality of mushroom with following objectives.

1. To study the characterisation of substrates used for mushroom cultivation,
2. To find out suitable substrate for optimum yield of mushroom,
3. To find out suitable substrate for production of better quality mushroom and
4. To study the quality of mushroom grown on different substrates.

Chapter Opener Page

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

A brief review of literature pertaining to the "studies on the effects of different substrates on yield and quality of mushrooms (Sp. *Pleurotus sajor-caju*)" is given in this chapter.

2.1 Effects of Temperature and humidity on yield and quality of mushrooms

Trreschow (1944) observed that the mycelium of the *Agaricus bisporus* was very sensitive to temperature and optimum growth was observed in a very narrow range of temperature. Rangaswami (1956) found that paddy straw mushroom (*Volvariella diplasia*) have good growth in the nutrient medium at 35^{o}C temperature. Flegg and Gandy (1962) studied the different environmental factors on the yield of *Agaricus bisporus*. He reported that initiation of primordia was delayed when the cropping room was not properly ventilated, this resulted in reduction in the yield, low humidity (40-50%) and high temperature (75^{o}F) reduced the yield. The yield was highest at 80-90% relative humidity and 65^{o}C temperature. Rath (1962) found that (*Volvariella diplasia*) grow well in the tropics on paddy straw because of their suitability for high temperature and tropical climate. Kindt (1968) subjected four mushroom strains of *Agaricus bisporus* to different rate of watering. He observed that water gives too late or too small had negative influence on yield, average weight of button and earliness of crop. Ramkrishnan *et al.*, (1968) reported that 35.6 to 37^{o}C was the most favourable temperature for the maximum production of sporophores in case of *Volvariella diplasia*. Huhnke (1969) observed that substrate temperature ranging from 14 to 30°C was optimum for mycelium growth phase while the lethal temperature was 36°C. Mycelial growth was retarded at temperature above and the below optimum.

Gupta *et al.*, (1970) found optimum temperature and humidity for the production of good crop of paddy straw mushroom to be 30 to 40°C and 57.2% respectively. The optimum temperpature for the development of mycelium of *Agaricus bisporous* was 25°C while the growth of fruit bodies required to an optimum temperature of 16 to 18°C. Vedder (1973) observed that average total water consumption was two liters per kg of mushroom. Flegg (1974 and 1975) observed that the cultivation of *Agaricus bisporus* the amount of water applied was positively co-related with crop weight. Similarly, favourable effect of water sprays on the weight of *Agaricus bisporus*. Leong (1980) successfully obtained good yield of *Pleurotus florida* when cultivated on cotton waste. He observed that holding the beds at 20°C for 15 days during cropping gave better yields. Poochow (1980) reported that 20°C was found suitable temperature for oyster mushroom. Sharma (1983) studied the temperature and humidity effect on *Pleurotus sajor-caju*. The dry weight of *Pleurotus sajor-caju* at cropping temperature of 12-16°C is 7.34 to 3.85% more as compared to that of cropping temperature of 27-32°C. The cropping temperature 17-22°C better for quality. Yang (1984) studied the effect of light on growth of mushroom mycelium. He observed that strong illumination (600ix) and complete darkness had little effect. The mycelium grew well under yellow and green light but growth was inhibited under red & blue light.

Laborde (1987) studied the cultivation of *Pleurotus ostreatus* and gave the recommondation on different aspects of mushroom cultivation. Jadhav *et al.*, (1991) observed the better yield of mushroom on pasteurized straw than non pasteurized straw and recommanded particular chemicals and combination of same.

2.2 Chemical composition of substrate before to mushroom cultivation :

Smith and Hayes (1972) reported a good yield of button mushrooms when the C:N ratio of various substrate was 17:1. Goh and Graham (1975) successfuly grew paddy straw mushroom (*Volvariella volvacea*) on a compost made from 90% oil palm pericarp waste and 10% shredded waste paper supplemented with 0.6% urea or 0.5% NaOH out of three pericarp paper combinations the one supplemented with urea gave maximum yield per unit area. Mueller *et al.*, (1985) used celluosic residues clarifier sludge from a bleached kraft pulp mill as a substrate and were analysed for minerals and heavy metals. They found the same chemical composition of Pleurotus fruit bodies grown on rice straw. Hemics and Voros (1985) reported change in crude protein lipid and fiber content of maize stalk when used for cultivation of *Pleurotus ostreatus*. They suggested the use of spent substrate for feeding to cattle and sheep. Bisaria *et al.*, (1987) reported that the biological efficieny of *Pleurotus sajor-caju* was maximum on paddy straw supplemented with cotton seed. They cultivated *Pleurotus sajor-caju* on different agro residues and the mineral content of fruit bodies were determined. They found that potassium content was the highest followed by sodium and manganees. They found mineral content of fruit bodies grown on different substrates. In general the content of a particular element in fruit bodies was found to be higher when cultivated on substrate containing higher content of that element. Amanat *et al.*, (1987) used wheat and paddy straw for the cultivation of *Pleurotus ostreatus.* They reported an increase in the crude protein content of both the straw with fungal treatment. In wheat straw the crude protein content was increased (3.45% to 5.33%) and in rice straw (6.52% to 12.68%). The fungi treatment drastically reduced the content of hemicelluloses from 25.10 to 16.28% in wheat and from 15.36 to 8.47% in rice straw. They also reported decrease in Neutral Detergent Fibre (NDF) in both the straw while an increase in the Acid Detergent Fiber (AFD) after the fungal treatment the IVDMD value of rice straw was well improved however no improvement in IVDMD value of wheat straw was noticed.

Khalon and Das (1987) used paddy straw for the cultivation of *Pleurotus ostreatus*. They reported an increase in dry matter digestibility, significant degradation of cellulose and legnin with an increase in IVDMD value of the spent straw. It was also observed the crude protein content was also increased upto 9%.

Balasubramanya and Bhatwadekar (1988) used enriched acid hydrolysed and alkali neutralized substrates like paddy straw wheat straw, cotton stalk, tur stalk and groundnut hulls with *Pleurotus sajor-caju*. There was two folds increase in crude protein in paddy straw and groundnut hulls and 1.5 folds increase in respect of other substrates. Lavie (1988) used cotton straw as growth substrate for the cultivation of oyster mushroom. He reported that the cotton straw previously unusable as fodder due to its high lignin content becomes digestible and nutritious feed for cattle and sheep. Prabhu *et al*., (1991) analysed the substrates such as paddy straw, maize cobs, coir dust and groundnut shells periodicaly during cropping mushroom for carbon, nitrogen, water soluble and ethanol benzene soluble extracts, cellulose, lignins and hemicelluloses.

2.3 Effect of different substrate on yield of mushroom.

Bano and Shrivastava (1962) used different substrates like rice straw, sorghum straw, rice hulls, saw dust, horse dung and various combination of these material for the cultivation of *Pleurotus species* and they observed that the highest yield was obtained from rice straw. Shin *et al*., (1971) observed that the yield of mushroom was highest on a substrate combination of rice straw, poultry manure, rice bran, urea and gypsum. They further reported that out of eleven farm products tested parilla meal, sesamum meal, wheat bran, poultry manure and rice bran were highly effective in increasing the yield. Ranchva (1973) reported that compost of wheat straw + dry maize stem + corn cobs produced almost as high yield as that was produced on the compost containing chicken manure. Jandaik and Kapoor (1974) cultivated *Pleurotus sajor-caju* on farm waste products such as banana psudostems, paddy and wheat straw compost and saw dust, they obtained good yield with banana psudostems and chopped paddy straw. Bano *et al*., (1979) conducted experiment at Mysore and

T-3266

obtained high yield of *Pleurotus flabellatus* on rice straw as against wheat and ragi straw. Poo Chow (1980) obtained highest yield of oyster mushroom using cotton waste as a substrate held at 20°C for 15 days spawn run period. Sivaprakasam and Kandaswamy (1981) obtained more yield (183 g/m^2) of *Pleurotus sajor-caju* on waste paper substrate compared to sugercane bagasse (176 g/m^2) hulled and powdered maize cobs (173 g/m^2) and rice straw (163 g/m^2) however number of mushroom per m^2 viz. 28, 35, 33 respectively did not corelate with yields.

Platt *et al.*, (1982) observed higher yield of *Pleurotus ostreatus* on chopped cotton straw as compared to wheat straw. They also found better spawn run and early fruiting on cotton straw as compared to wheat straw. Similar beneficial effect of cotton straw on yield of oyster mushroom has been reported by Lavie (1988). Khanna and Garcha (1982) tried four sp. of mushroom. They found that yield of *Pleurotus sajor-caju* was comparatively higher than other species, on paddy straw. Bisaria *et al.*, (1987) reported that the biological efficiency of *Pleurotus sajor-caju* was maximum on paddy straw supplemented with cotton seed.

Ramesh and Ansari (1987) used several locally available substrate such as rice straw, banana leaves, sawdust, oil palm refuse, oil palm bunch refuse or grass straw to study conversion efficiency of *Pleurotus sajor-caju*. Rice straw and banana leaves were the best substrate with 60% and above conversion efficiency on dry weight basis. The mean weight of the fruiting body was high (7.1 g) on banana leaves compared with other substrates (2.1

- 5.0 g). The spawn running time was also less with banana leaves followed by rice straw, grass straw, oil palm bunch refuse, saw dust and oil palm waste. Shivprakasam *et al*, (1987) observed highest yield of *Pleurotus sajor-caju* on paddy straw filled in polybags followed by the same substrate filled in bamboo baskets. Silankove *et al*., (1988) reported *Pleurotus* Sp. cultivated on cotton straw and combination of cotton (50%) and wheat straw (50%) the yield of edible mushroom was maximum on the wheat + cotton straw substrate. The ligno-cellulose content of the used substrates was decreased and detergent soluble content increased, indicating an improvement in the quality of the substrate as feed stuff. Madan *et al*., (1989) reported a good yield of *Pleurotus sajor-caju* on a substrate containing silk worm litter and paddy straw in 1:4 proportion. Patil *et al*., (1989) grew *Pleurotus sajor-caju* on different five straw, jawar, *bajra*, cotton, paddy and maize. Wheat straw and reported that the highest yield was obtained on cotton straw followed by Jawar straw and maize straw produce lowest yield. Mahmoud *et al*., (1989) reported that yield was significantly increased by supplementation of wheat bran, dried green clover and soybean flour in to paddy straw.

Rajarathnam *et al*., (1990) reported highest fruit bodies on a substrate content paddy straw and seeds of cotton. Rana and Suhag (1991) used various legume waste of gram, green gram, black gram pigeon pea, cow pea, soybean for the cultivation of *Pleurotus sajor-caju*. Satisfactory results could not be achieved due to growth of weed fungi in compost during spawn running, however gram legume pod waste in combination with wheat straw improved yield by 5-26%. Maximum yield was harvested from adding soybean pod waste. Sharan *et al.*, (1991) obtained good yield of *Agaricus bitroquis* when the substrate was supplemented with mustard cake. Prabhu *et al.*, (1991) utilized various straws viz. paddy straw, maize corns, coir dust and groundnut shells. They observed increase in per cent carbon and per cent nitrogen during cropping of *Pleurotus sajor-caju*. The yield of *Pleurotus sajor-caju* was found significantly higher on paddy straw. Khandar *et al.*, (1991) utilized different substrates such as jawar straw paddy straw groundnut pod shells, paddy straw + groundnut pod shells, paddy straw + groundnut pod shells (1:1 w/w) and Jawar straw + groundnut pod shells. They found that jawar straw gave significantly higher yield than other substrates. Singh and Singh (1991) used soybean straw, wheat straw and paddy straw alone as well as in combination. The highest yield recorded on soybean straw alone (729 g./ 1000 g). The combination of wheat straw + soybean straw gave highest yield over other combination. Thilagavthy *et al.*, (1991) reported that maximum yield of oyster mushroom on Banana pseudostem over silk, cotton chips, millet stalk and sorghum stalk. Savalgi *et al.*, (1991) tested three species of oyster mushroom *P. ostreatus*, *P. sajor-caju*, *P. florida* seven substrates viz. wheat straw, paddy straw, stalk of jawar, maize stalk and cobs, cotton waste, sunflower husk, groundnut shell and husk with different additives. The result indicated that all substrates were suitable for cultivation of oyster mushroom. Patil *et al.*, (1991) tested different fourteen substrates seperately and in three combination of selected substrates for productivity at AICMIP. College of

Agriculture, Pune-5. Among fourteen substrate the cotton stalk produced significantly higher yield and it was followed by wheat and paddy straw. All other substrates produced yield in the range of 305 to 965 g/kg of dry substrate and sugercane trash recorded the lowest yield.

2.4 Effect of different substrates on quality of mushroom.

Bano *et al.*,(1981) reported different species of Pleurotus cultivated on paddy straw substrate and analysed for minerals like potassium, phosphorus, magnesium, sodium, calcium, copper, zink and mercury. Potassium, phosphorus and magnesium were the major constituents of ash. The lead, cadmium, zink, copper of all the four species ranged from 1.5 to 3.25; 0.3 to 0.55, 58.6 to 129.0 and 12.2 to 21.9 ppm (on dry weight basis) respectively moisture content of all the samples ranged from 90.0 to 92.0%. Sharma (1983) observed that the average weight of sporophores increased with the rise in substrate moisture. However there was no effect of moisture content of the substrate on time of maturity. Khanna and Garcha (1984) studied the nuclic acid content of four species of *Pleurotus* which found to range from 2.46 - 2.91% on dry weight basis. More than 50% of the total nuclic acid was found to be RNA. The relative nutritive value (RNV) and protein efficiency ratio (PER) of sporophore proteins of *Pleurotus florida* and *Pleurotus sapidus* were close to that of standard protein casein when evaluated by the treahymena pyriformis assay. Khanna and Garcha (1986) observed the nutritional value of four *Pleurotus* species and stated that pleurotus sporophore were good source of protein. They assessed the proximate composition of mushroom for moisture, crude protein, fat, ash, carbohydrate on dry weight basis. *Pleurotus memberanus* and *Pleurotus sajor-caju* contained higher dry matter, total carbohydrate, vitamin C than other. Bisaria *et al.*, (1987) cultivated *Pleurotus sajor-caju* on different agro residue and the mineral content of fruit bodies were determined. They found the potassium content was the highest followed by sodium and manganees. They studied mineral content of fruit bodies grown on different substrate. Jain *et al.*, (1988) used the acquatic weeds for the cultivation of *Pleurotus sajor-caju* and observed that water spinach (*Imomoea acquatica*) could best support mushroom growth followed by water volvet. (*Azolla pinnata*) and duck weed (*Lemna minor*). The composition of mushroom fruit bodies grown on all three substrates was more or less the same. The nitrogen content of the spent substrate was enhanced making them a better source of organic fertilizer. Rai and Sexena (1988) tested seven *Pleurotus* Sp. for comparative nutritional value under identical condition and assessed the dry matter, carbohydrate, protein reducing and non-reducing sugars, vitamin C. Gujaral *et al.*, (1989) used different acquatic weeds for the cultivation of *Pleurotus sajor-caju*. They observed that mushroom cultivation was useful for converting agro-residues into energy rich food. Iqbal and Ashr (1989) reported that cotton waste was the best substrate for cultivation of oyster mushroom.

Mostafa *et al.*, (1991) observed the composition of fruit bodies and reported that the as protein content ranged from 13.2% to 14.3%, carbohydrate from 56.6% and 52.2% in *Pleurotus florida* and *Pleurotus sajor-caju* respectively. The fat was 5.79%

and 7.70% in *Pleurotus florida* and *Pleurotus sajor-caju* respectively. Fiber and ash content were within the values reported by others. The content of minerals in sporophores like phosphorus, calcium was reported to be higher than many fruits and vegetables.

2.5 Chemical composition of different spent substrate (after mushroom cultivation)

In mushroom industry huge quantity of wastes (spent compost and spent straw) are disposed every year which contribute towards environmental pollution, health hazards and serves as a constant source of pest and pathogens to mushrooms. Though being used as cattle feed, high lignification and low crude protein content made them less nutritious than green fodder. Physical, chemical and microbial treatment of the cellulosic material have been tried for improving nutritive value of such materials to the animal (Anonymous April, 1994). Lynch *et al.*, (1977) utilized several fungi for degradation of cellulosic material and their by improving nutritive value of straw. Zadrazil (1977) observed that the straw subjected to the mushroom growth had better *in vitro* digestibility and hence this can be a source of valuable cattle feed. Kurtzman *et al.*, (1979) reported an increase in nitrogen content of different substrates due to presence of nitrogen fixing bacteria in the bed. Longar *et al.*, (1980) studied the composition and *in vitro* digestibility of the spent wheat straw after the cultivation of *Agaricus bisporous*.

Shetty and Krishnamoorthy (1981) reported an enrichment of paddy straw with the cultivation of *Pleurotus sajor-caju* and suggested its possible use as animal feed. Bakshi and Longer (1985) replaced the concentrate mixture by spent wheat straw upto 40% on nitrogen basis in buffalo feed and reported that the nitrogen from spent straw was available to the buffalo as an ingredient in the concentrate mixture. Mueller *et al.*, (1985) studied the chemical composition of spent straw and mushroom fruit bodies on cellulosic residuces clarifier sludge and rice straw and reported that same composition of mushroom fruit bodies grown on cellulosic residuces clarifier sludge and rice straw. Hemics and Voros (1985) reported change in crude protein, lipid and fibre content of Maize stalks when used for cultivation of *Pleurotus ostreatus*. They suggested the use of spent substrate for feeding to cattle and sheep. Ortaga *et al.*, (1986) reported *Pleurotus ostreatus* cultivated on barly straw for 45-60 days. They found significant reduction in hemicellulose and cellulose content in straw utlized for mushroom cultivation, however there was no difference in the crude protein content. Amanat *et al.*, (1987) utilized wheat and paddy straw for the cultivation of *Pleurotus ostreatus*. They reported an increase in the crude protein content of the both the straw with fungal treatment in wheat straw. The crude protein content of wheat straw increased from (3.45% to 5.33%) and in rice straw from (6.52% to 12.68%). The fungi treatment dramatically reduced the content of hemicellulose from 25.10 to 16.28% in wheat and from 15.36 to 8.47% in rice straw. Chawla and Kundu (1987) reported high crude protein of wheat straw when utlized for cultivation of

Volvariella volvacea. Khalon and Das (1987) used paddy straw for the cultivation of *Pleurotus ostreatus*. They reported an increase in dry matter digestibility. Significant degradation of cellulose and legnin with an increase in IVDMD value of the spent straw was observed. The crude protein content was also increased upto 9%. Zadrazil (1987) used edible species of basidiomycets and other Ascomycet fungi for growth and fruit body production and an increase in *in vitro* digestibility of wheat straw and other lignocellulosic materials was reported. Good results in terms of higher yield of fruiting bodies and increased IVDMD value obtained with pleurotus cultivation was also reported. Bisaria *et al*., (1987) reported *Pleurotus sajor-caju grown on number* of agro-residue and their mixture. They reported that number of biochemical changes affected by cultivation of mushroom in terms of nitrogen content and degradation of cellulose, hemicellulose and lignin components. Balasubramanya and Bhatwadekar (1988) enriched acid hydrolyzed and alkali neutralized substrates like paddy straw, wheat straw, cotton stalk, tur stalk and groundnut hulls with *Pleurotus sajor-caju*. There was two fold increase in crude protein in paddy straw and groundnut hull and 1.5 fold increase with the others. Gupta and Longar (1988) reported an upgradation of nutritive value of wheat straw used for the cultivation of *Pleurotus florida*. Kulkarni and Nagraja (1988) reported increase in the nitrogen content of wheat straw with the cultivation of *Pleurotus* Sp. Li and Yang (1989) reported a decrease in crude ash content, crude fiber and crude protein content of cotton waste utilized for cultivation of *Pleurotus* *sapidus*. The spent mushroom compost has also been utilized as soil, amendment for improving the crop production.

Sharma and Jandaik (1991) studied to cultivate *Pleurotus ostreatus* and *Pleurotus florida* on spent straw compost. Maximum biological efficiency (B.E.) were obtained on wheat straw followed insignificantly by wheat straw + spent straw (75:25 w/w) giving biological efficiency 75.55% respectively. The yield obtained (B.E. 74.44%) of *Pleurotus ostreatus* on wheat straw + spent straw (50 : 50) was at par with the yield obtained on spent straw alone (B.E. 67.77%). Prabhu *et al.*, (1991) examined the substrates such as paddy straw, maize cobs, coir dust and groundnut shells, periodicaly at 0, 24 and 50th day of cropping of mushroom for carbon, nitrogen, water soluble and ethanol benzene soluble extracts, cellulose, lignins and hemicellulose.

Chapter Opener Page

MATERIAL AND METHODS

3. MATERIALS AND METHODS

The present study was undertaken to observe the "Effects of different substrates on yield and quality of mushroom (Sp. *Pleurotus sajor-caju*)" in the year 1994-95.

3.1 Experimental site.

Various trials of the research work relating to the cultivation of *Pleurotus sajor-caju* were carried out at All India Co-ordinated Mushroom Improvement Project (ICAR) College of Agriculture, Pune, under Mahatma Phule Krishi Vidypeeth. Rahuri, Dist. Ahmadnagar. Analysis of mushrooms and straws were carried out at Agriculture Chemistry and Soil Science Department, College of Agriculture, Pune-5.

3.2 Climatic conditions :

Pune is located on 18-32^{o} N Latitude and 73.51^{o} E Longitude. The climatic conditions prevailing in the area has annual rainfall of 650-750 mm well distributed over the period of Season. The maximum summer seldom goes above 42^{o}C while minimum temperature rarely falls below 5^{o}C.

3.3 Mushroom culture :

The master culture of mushroom fungus (*Pleurotus sajor-caju*) was obtained from the All India Co-ordinated Mushroom Improvement Project (ICAR) College of Agriculture, Pune. Same culture was used for the preparation of master and commercial spawn in experiments.

3.4 Preparation of master and commercial spawn :

During the entire research experiment unbroken wheat grains were used for preparation of master and commercial spawn.

3.4.1 Master spawn :

The wheat grains which were not old or broken selected and boiled by using equal volume of water till the entire water is absorbed by the grains. Utmost care was taken that grains would not split or break which give out starch and become soft. These boiled grains were spread over a fine wire mesh for drain out excess water . After draining of water grains were mixed throughly with 3% calcium carbonate powder and filled in 500 ml bottles up to 2/3 of capacity and plugged with non absorbent cotton wool. These plugged bottles were sterilized in autoclave at 30 Lbs p.s.i. for 30 minutes for two consecutive days with an interval of 24 hours between two autoclaving.

After completion of the autoclaving, these bottles were cooled under normal temperature (25^{o}C) and inoculated with previously prepared mycelial bits from master culture tubes. The inoculation of mycelial bits were carried out on sterilized stainless steel bench in horizontal laminar flow to avoid contamination and these bottles were incubated at 24^{o}C $\pm$ 2 in incubator. After seven days the incubated bottles were shaken vigorously for breaking mycelial threads and well mixed with the grains. After two weeks uniform white fungal growth was obtained around all the grains. This culture were further multiplied for commercial spawn production under the present investigation.

3.4 2. **Commercial spawn.**

The commercial spawn used in different trials of the present investigation was prepared by using wheat grains. The master spawn was used to inoculate the grain bottles insted of mycelial bits of master spawn. After inoculation of mycelial wheat grains in bottles containing grains, these bottles were incubated at $24^{o}C \pm 2^{o}C$ and good uniform mycelial growth was seen within 12 to 15 days.

3.4 3. Experimental details :

The present investigation was laid out in a completely Randomized Block Design at All India Co-ordinated Mushroom Improvement Project (ICAR) College of Agriculture, Pune. There were ten treatments and each treatment was replicated three times. The plan of layout of the experiment is presented in Table 1. The schedule of operation involved during cultivation of mushroom is given in Table 2.

Table 1. Details of Treatments

Sr. No.	Treatments	Symbol	Replications	Quantity of straw
1	Wheat straw	T1	T1R1	1 Kg
			T1R2	1 Kg
			T1R3	1 Kg
2	Paddy straw	T2	T2R1	1 Kg
			T2R2	1 Kg
			T2R3	1 Kg
3	Bajra stalks and leaves	T3	T3R1	1 Kg
			T3R2	1 Kg
			T3R3	1 Kg
4	Maize stalks and leaves	T4	T4R1	1 Kg
			T4R2	1 Kg
			T4R3	1 Kg
5	Jowar stalks and leaves	T5	T5R1	1 Kg
			T5R2	1 Kg
			T5R3	1 Kg
6	Cotton stalks and leaves	T6	T6R1	1 Kg
			T6R2	1 Kg
			T6R3	1 Kg
7	Soyabean straw	T7	T7R1	1 Kg
			T7R2	1 Kg
			T7R3	1 Kg
8	Groundnut creepers + wheat straw (1:1)	T8	T8R1	1 Kg
			T8R2	1 Kg
			T8R3	1 Kg
9	Soyabean straw + wheat straw (1:1)	T9	T9R1	1 Kg
			T9R2	1 Kg
			T9R3	1 Kg
10	Groundnut creepers	T10	T10R1	1 Kg
			T10R2	1 Kg
			T10R3	1 Kg

ABSTRACT DIGITIZED

Table 2. Operations carried out during cultivation of Mushroom

Date	Operations
3-9-94 to 10-9-94	Collection of different substrates
14-9-94 to 15-9-94	Chopping of straw into small pieces of 2-5 cm size
16-9-94	Soaking of different straw in water for ten hours
19-9-94	Bed filling
20-9-94	Allowed the beds for 15 days incubation period
5-10-94	Removed the polythene bags
6-10-94	Water was regularly given for two times a day
15-10-94 to 17-10-94	Harvested first flush of mushrooms
17-10-94	Scrapped 1 cm layer of straw from all round beds
18-10-94	Watering was given two times a day for eight to ten days
27-10-94 to 29-10-94	Harvested second flush of mushrooms
29-10-94	Scrapped 1 cm layer of straw from all round beds
7-11-94	Harvested third flush of mushrooms

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3.4 4 Substrates

The substrates were collected from the farm of Agronomy Department, College of Agriculture, Pune. After collection they were well dryed and carefully stored. These substrates were chopped into small pieces of 3-5cm length. This material was soaked in water for 5-24 hrs., it was then removed and allowed to drain off the excess water. After draining of water, these substrates were sterilised in hot water at 80^{o}C for about 1 hour. After sterilization the material was allowed to cool to ambient temperature and excess water allowed to drain off. The pH of substrateS was adjusted to neutrality by adding of appropriate quantity of $CaCO_3$. This straw was used for filling in the polythene bags. The moisture in each straw was maintained in the range of 60-70%.

3.5 Cultivation method

The standard polythene bag method of cultivation of *Pleurotus sajor-caju* on different agricultural wastes was followed in all the experiments. The details of the cultivation method described as under.

3.5.1 Polythene bags :

In the cultivation of *Pleurotus sajor-caju* polythene bags were used having size of 35 X 55 cm. and bags were sufficient to accomodate 1 Kg of dry substrate. Bags were provide with holes all round the beds with the help of pin. Before use these bags were sterilized by dipping in 2% formalin solution.

3.5.2 Spawn

Good mycelial growth all around the grain produced from master spawn was maintained and used. The spawn used at the rate of 2% of wet weight of substrate.

3.5.3 Cultivation room

The cultivation room of All India Co-ordinated Mushroom Improvement Project (ICAR) were particularly ventilated with diffused light. During the research work period temperature prevaled in the average range of 20.62 - 25.01°C. In the cropping room water was sprinkled over the walls and floor of room for maintaining the relative humidity during cultivation in the average range of 83.05 - 85.69%. And care was taken for the proper air circulation in the growing room. Humidity and temperature in cultivation room was recorded by hygrometer and thermometer, which are presented in Table 3.

3.5.4 Cultivation technique

The procedure of cultivation of oyster mushroom as described by Bahl (1981) was adopted. A laboratory bench was selected with low air movement for filling the bags. The surface of bench was sterilised with 2% formalin solution before use. In the bag first layer of sterilised straw was laid at about 7 to 10 cm. The spawning was completed by spreading a spawn in between 5 cm layer of straw. There were six layers of substrates followed by spawn were kept for each treatment. This material were gently pressed to have round shape.

Table 3. Relative humidity and temperature during cultivation of mushroom in the room

Date	Temperature (°C)		Relative Humidity (%)	
	Minimum	Maximum	8.30 a.m.	2.30 p.m.
01.09.94	21.40	25.30	86.00	88.00
02.09.94	21.00	24.60	80.00	84.00
03.09.94	21.00	26.20	79.00	82.00
04.09.94	21.40	26.20	86.00	88.00
05.09.94	21.20	25.30	84.00	89.00
06.09.94	21.40	26.20	82.00	88.00
07.09.94	21.40	26.30	84.00	86.00
08.09.94	21.00	25.10	84.00	89.00
09.09.94	20.70	25.40	82.00	84.00
10.09.94	20.40	25.30	85.00	89.00
11.09.94	19.40	25.30	80.00	84.00
12.09.94	19.80	25.20	83.00	88.00
13.09.94	21.50	26.50	86.00	82.00
14.09.94	19.00	24.50	87.00	89.00
15.09.94	19.00	26.00	84.00	86.00
16.09.94	20.30	25.00	86.00	85.00
17.09.94	20.50	22.20	88.00	86.00
18.09.94	21.00	25.10	84.00	87.00
19.09.94	20.50	24.50	79.00	84.00
20.09.94	19.20	25.50	83.00	86.00
21.09.94	21.00	25.20	82.00	89.00
22.09.94	20.50	26.20	81.00	85.00

Contd....

Date	Temperature (°C)		Relative Humidity (%)	
	Minimum	Maximum	8.30 a.m.	2.30 p.m.
23.09.94	21.00	27.00	82.00	88.00
24.09.94	21.00	26.50	81.00	86.00
25.09.94	20.50	25.50	86.00	88.00
26.09.94	19.80	26.50	85.00	88.00
27.09.94	19.90	26.50	85.00	89.00
28.09.94	22.50	25.20	87.00	89.00
29.09.94	20.50	26.20	86.00	88.00
30.09.94	21.00	25.00	82.00	86.00
01.10.94	20.50	25.50	81.00	85.00
02.10.94	19.90	24.20	88.00	87.00
03.10.94	22.70	25.00	86.00	82.00
04.10.94	20.90	25.50	85.00	88.00
05.10.94	20.50	24.50	81.00	85.00
06.10.94	19.10	25.00	85.00	86.00
07.10.94	19.80	24.20	84.00	87.00
08.10.94	20.00	25.00	81.00	82.00
09.10.94	21.00	24.50	84.00	85.00
10.10.94	19.90	23.90	85.00	88.00
11.10.94	21.50	24.80	79.00	81.00
12.10.94	20.50	25.00	85.00	88.00
13.10.94	21.40	24.20	82.00	84.00
14.10.94	21.40	27.50	82.00	85.00
15.10.94	21.20	26.50	82.00	86.00

Contd....

Date	Temperature (°C)		Relative Humidity (%)	
	Minimum	Maximum	8.30 a.m.	2.30 p.m.
16.10.94	20.20	26.00	80.00	81.00
17.10.94	22.00	25.90	84.00	85.00
18.10.94	20.50	26.20	81.00	83.00
19.10.94	19.20	27.50	86.00	89.00
20.10.94	20.20	25.90	81.00	83.00
21.10.94	21.50	23.10	84.00	85.00
22.10.94	21.00	24.50	81.00	83.00
23.10.94	21.30	25.50	82.00	86.00
24.10.94	21.00	25.50	86.00	88.00
25.10.94	21.90	25.50	85.00	87.00
26.10.94	19.90	26.20	87.00	88.00
27.10.94	20.30	26.50	82.00	86.00
28.10.94	20.50	26.30	83.00	89.00
29.10.94	21.00	25.40	83.00	85.00
30.10.94	21.40	24.90	84.00	87.00
31.10.94	21.20	24.80	79.00	82.00
01.11.94	21.50	25.10	82.00	85.00
02.11.94	19.00	25.30	83.00	85.00
03.11.94	20.00	25.30	81.00	84.00
04.11.94	21.00	21.20	85.00	86.00
05.11.94	19.50	23.80	86.00	89.00
06.11.94	20.20	25.20	84.00	86.00
07.11.94	19.50	25.20	80.00	82.00

Contd....

Date	Temperature (°C)		Relative Humidity (%)	
	Minimum	Maximum	8.30 a.m.	2.30 p.m.
08.11.94	20.00	25.30	81.00	84.00
09.11.94	21.10	25.30	78.00	82.00
10.11.94	21.00	24.80	86.00	88.00
11.11.94	19.90	24.30	85.00	87.00
12.11.94	20.50	24.80	84.00	86.00
13.11.94	19.90	25.30	82.00	84.00
14.11.94	21.00	26.00	83.00	85.00
15.11.94	21.40	26.10	86.00	89.00
16.11.94	21.80	26.50	81.00	85.00
17.11.94	20.20	21.30	81.00	84.00
18.11.94	20.40	24.80	82.00	86.00
19.11.94	20.40	24.40	80.00	83.00
20.11.94	19.30	23.50	84.00	86.00
21.11.94	19.00	23.40	83.00	85.00
22.11.94	21.10	23.40	81.00	84.00
23.11.94	19.90	21.60	87.00	89.00
24.11.94	19.90	21.60	82.00	84.00
25.11.94	21.00	23.00	87.00	89.00
26.11.94	19.50	21.70	75.00	80.00
27.11.94	21.00	22.30	82.00	85.00
28.11.94	22.50	24.30	81.00	84.00
29.11.94	21.00	25.30	79.00	82.00
30.11.94	21.50	25.60	80.00	84.00
Average	20.62	25.01	83.05	85.69

The bags were then tied at top with string and kept in growing room for spawn running in well ventilation room. After 15-20 days the spawn run completion observed by white growth of mushroom fungus all over the straw. After completion of spawn run these bags were cut down longitudinally by using sharp stainless steel blade and the polythene was removed and these solid blocks of substrates put on the rack of cultivation room and watered regularly to keep the beds moist once a day. Observations on the appearance of sporophore, size of sporophore and stipe length were recorded. Harvesting was done before spore shedding by twisting the mushrooms with fingers. After harvesting the first flush, the substrate layer of about 1 cm was scrapped and watering was done regularly as and when required.

3.6 Details of observations

3.6.1 Pileus size

A fresh pileus was taken and gently pressed on plane white paper. The area of pileus was drawn by pencil and measured by leaf area meter. Three pileuses (fresh) were randomly taken from each and measured average area (size) and mentioned in Table 13.

3.6.2 Stipe length (cm)

The stipe length of fresh mushroom was measured from its base to the point of attachment to pileus with [illegible] scale Three samples randomly taken and average stipe length quoted in Table No.13.

3.6.3 Days required for first flush

This was calculated simply from the difference between date of bed filling and date of full growth of sporophore attained. The average number of days required for full growth of sporophore of three samples were recorded and presented in Table 13.

3.6.4 Number of sporophore

This was simply counted by counting the number of sporophore and average was shown in Table No 14.

3.6.5 Weight of sporophore

Three fresh mushroom sporophores were harvested from each treatment and average weight was shown in Table 14.

3.6.6 Yield

Three beds of mushroom were harvested from each treatment. The total fresh flush wise average weight was recorded.

3.6.7 Biological efficiency

The per cent biological efficiency was calculated by

$$= \frac{\text{Fresh weight of the mushroom (g) bag}}{\text{Dry weight of the substrate (g)}} \times 100$$

3.7 Methods of chemical analysis

3.7.1 Analysis of original straw and spent straw

The original straw and spent straw samples were taken and oven dried in a hot air oven. After oven dried the samples was powdered with electrical grinder. The fine powdered sample was taken and digested with mixture of concentrate sulphuric acid and hydrogen peroxide (30%) as described by Parkinson and Allen (1975). After digestion of fine powder, the volume was made with distilled water to 100 ml. A suitable quantity of aliquot was taken for further chemical analysis. The methods of analysis which are used were presented in Table 4.

3.7.2 Analysis of fresh mushroom

The three mushroom samples from each treatment were selected randomly and digested with the diacid mixture as described by Parkinson and Allen (1975) and after complete digestion the suitable aliquot was taken for further analysis. Fresh samples of mushrooms were taken for estimation of crude fat, crude fibre, carbohydrate and calcium, phosphorous and iron. The methods which were used for analysis of straw, spent straw and proximate composition of mushroom are quoted in Table 4.

3.8 Statistical Analysis and interpretation of data

The data recorded were statistically analysed by adopting the technique of "Analysis of variance (Fisher, 1970) and test of significance was carried out as given by Cochran and Cox (1967), Panse and Sukhatme (1967). The statistical S.E. ± and C.D. were worked out and presented in Table.

Table 4. Methods used for analysis of straw, spent straw and mushrooms

Sr. No.	Determination	Method used	Reference
I)	**Analysis of straw and spent straw (Dry weight basis)**		
	Moisture	Gravimetric	A.O.A.C. (1975)
	Mineral matter	Ignition	A.O.A.C. (1975)
	Nitrogen	Micro-Kjeldahl	A.O.A.C. (1975)
	Crude protein	Micro-Kjeldahl (N x 6.25)	A.O.A.C. (1975)
	Phosphorous	Ammonium molybdate yellow colour method	Chapman and Pratt (1961)
	Organic carbon	Ignition	A.O.A.C. (1975)
	C:N ratio	Dividation	A.O.A.C. (1975)
	Calcium	Versenate	Jackson (1958)
	pH (1:30 straw to water)	Potentiometric	Jackson (1973)
II)	**Mushroom Analysis (Fresh weight basis)**		
	Moisture	Gravimetric	A.O.A.C. (1975)
	Mineral matter	Ignition	A.O.A.C. (1975)
	Crude protein	Micro-Kyeldah (N x 6.25)	A.O.A.C. (1975)
	Crude fat	Soxhelet extraction	A.O.A.C. (1975)
	Crude fibre	—	A.O.A.C. (1975)
	Carbohydrate	By substraction	A.O.A.C. (1975)
	Calcium	Versenate	Jackson (1958)
	Phosphorous	Ammonium molybdate yellow colour method	Chapman and pratt (1961)
	Iron	Atomic absorption spectrophotometer	Lindsey and Norvell (1978)

T. 3266

Chapter Opener Page

RESULTS AND DISCUSSIONS

4. RESULTS AND DISCUSSION

4.1. Effect of mushroom cultivation on chemical composition of different substrates

4.1.1 Moisture content.

The effect of *Pleurotus* cultivation on moisture content of different straw was recorded. Data on moisture content of different straws before and after cultivation of *P. sajor-caju* are presented in Table 4 and Fig. 1.

It would be seen from the data in Table - 4 that moisture content of straw before *Pleurotus* cultivation was observed in the range of 12.15 to 26.32% highest moisture content (26.32%) was found in soybean straw + wheat straw (T9) followed by soybean straw (T7) (25.98%) lowest moisture content 12.15% was seen in wheat straw (T1).

There was increase in the moisture content of spent straw after *Pleurotus* cultivation. Significant differences ranged from 21.16 to 37.12% in moisture content of different straw were also noticed . The highest increase was found in groundnut creepers (T10) 12.56 to 26.5% followed by bajra stalks and leaves (T3) 22.70 to 34.94%, while the lowest increase was found in T6 treatment (16.41 to 24.46%). Similar results were also reported by Prabhu Desai *et al.,* (1991). They reported that the paddy straw and coir dust showed marked increase in water soluble matter as cropping advanced. This is an indication of efficient substrate decomposition and biomass production by mushroom fungi.

Table 4. Effect of mushroom cultivation on moisture content of different substrates.

Treatments	Moisture (%)		% Increase/ Decrease
	Straw	Spent straw	
T1	12.15	23.99	+ 11.84
T2	17.54	25.95	+ 8.41
T3	22.70	34.94	+ 12.24
T4	16.15	25.29	+ 9.14
T5	13.48	21.45	+ 7.97
T6	16.41	24.46	+ 8.05
T7	25.98	34.42	+ 8.44
T8	12.91	21.16	+ 8.25
T9	26.32	37.12	+ 10.80
T10	12.56	26.50	+ 13.94
S.E. ±	0.07	0.04	
C.D. at 5%	0.21	0.12	

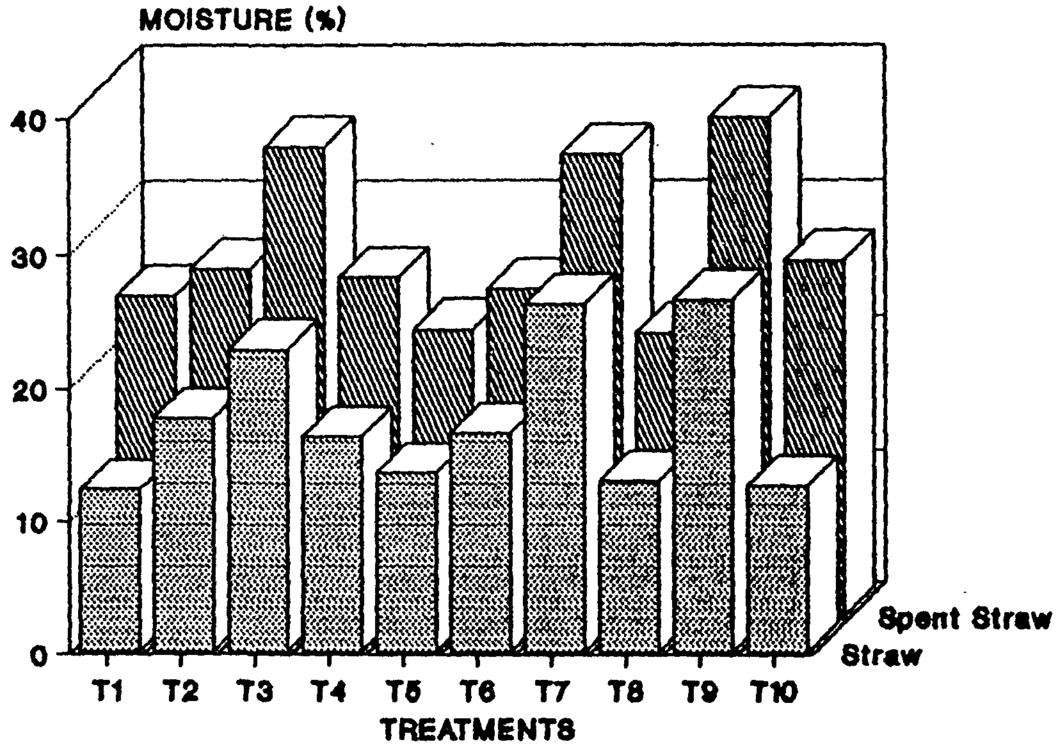

FIG. 1. EFFECT OF MUSHROOM CULTIVATION ON MOISTURE CONTENT OF DIFFERENT SUBSTRATES.

4.1.2 Nitrogen content

Data in respect of nitrogen content of different straws before and after *Pleurotus* cultivation are presented in Table 5 and graphically shown in Fig. 2. It can be seen from the data that the nitrogen content of straw before cultivation of *P. sajor-caju* significantly varied in the range of 0.49 to 1.02%. The highest nitrogen was found in T10 treatment (1.02%) followed by T7 (0.86%) and combination treatment T9 (0.86%), they were found statistically similar. Nitrogen content of T8 (0.82%) and T6 (0.80%) treatments was found at par with each other. The lowest nitrogen content was seen in the treatment T4 (0.49%). The nitrogen content of T3 (0.57%), T1 (0.52%) and T5 (0.50%) was more or less same. Data presented in Table revealed that nitrogen content of different straws increased nearly 2 to 3 folds due to cultivation of *P. sajor-caju*. Increase in N content was found in the range of 0.60 to 2.34 %. The highest nitrogen enhancement was found to be significant in cotton stalks and leaves (T6) (0.80 to 3.14%) followed by paddy straw (T2) (0.73 to 2.72%). The lowest nitrogen enhancement (0.86 to 1.46%)was found in combination of soybean straw + wheat straw (T9).

Bisaria *et al.*, (1987) also reported the highest increase in nitrogen content of wheat straw followed by Jowar straw used for cultivation of *P. sajor caju*.

An increase in nitrogen content of different substrates was due to the presence of nitrogen fixing bacteria in the bed (Kurtzman 1979). Jain *et al.*, (1988) They also reported increase in nitrogen content of acquatic weeds used for *P sajor-caju* cultivation.

Table 5. Effect of mushroom cultivation on nitrogen content of different substrates

Treatments	N (%)		% Increase/ Decrease
	Straw	Spent straw	
T1	0.52	2.06	+ 1.54
T2	0.73	2.72	+ 1.99
T3	0.57	1.95	+ 1.38
T4	0.49	1.25	+ 0.76
T5	0.50	1.89	+ 1.39
T6	0.80	3.14	+ 2.34
T7	0.86	2.09	+ 1.23
T8	0.82	1.92	+ 1.10
T9	0.86	1.46	+ 0.60
T10	1.02	1.75	+ 0.73
S.E. ±	0.011	0.013	
C.D. at 5%	0.032	0.038	

Similar results were also reported by Kulkarni and Nagraja (1988) and Thilagavathy *et al.,* (1991). Prabhu Desai *et al.,* (1991) also reported an increase in N content of different substrates when used for cultivation of *P. sajor-caju.*

4.1.3 Crude protein content

Data pertaining to the crude protein content of different substrates are presented in Table 6 and graphically represented in Fig. 3.

It can be seen from the Table 6 that the crude protein content of straw before cultivation of *P sajor-caju* was differed significantly The crude protein content of straw was found in the range of 3.06 to 6.37% . Highest crude protein content was obtained in T10 treatment (6.37%) followed by T7 (5.39%) and T9 (5.37%) which were statistically at par with each other. The lowest crude protein content was found in T4 treatment (3.06 %). i.e. maize stalks and leaves.

The increase in crude protein content of substrates under *P. sajor-caju* cultivation was varied significantly. The highest increase in crude protein content of substrate was seen under T6 treatment (5.01 to 19.62%) followed by T2 (4.58 to 17.03%). Increase in protein content of substrate under treatments T7 (5.39 to 13.06%) and T1 (3.27 to 12.87%) was found statistically at par with each other. The lowest increase in crude protein was seen in T9 treatment (5.37 to 9.16%).

These results are similar to those reported by Bisaria *et al.,* (1987). They reported the increase in crude protein content of wheat straw over paddy straw. Similar results in respect of spent straw were also reported by several workers

Table. 6. Effect of mushroom cultivation on crude protein content different substrates.

Treatments	Crude protein (%)		%Increase/ Decrease
	Straw	Spent straw	
T1	3.27	12.87	+ 9.60
T2	4.58	17.03	+ 12.45
T3	3.56	12.20	+ 8.64
T4	3.06	7.83	+ 4.77
T5	3.12	11.81	+ 8.69
T6	5.01	19.62	+ 14.61
T7	5.39	13.06	+ 7.67
T8	5.12	12.03	+ 6.91
T9	5.37	9.16	+ 3.79
T10	6.37	10.97	+ 4.60
S.E. ±	0.07	0.08	
C.D. at 5%	0.20	0.24	

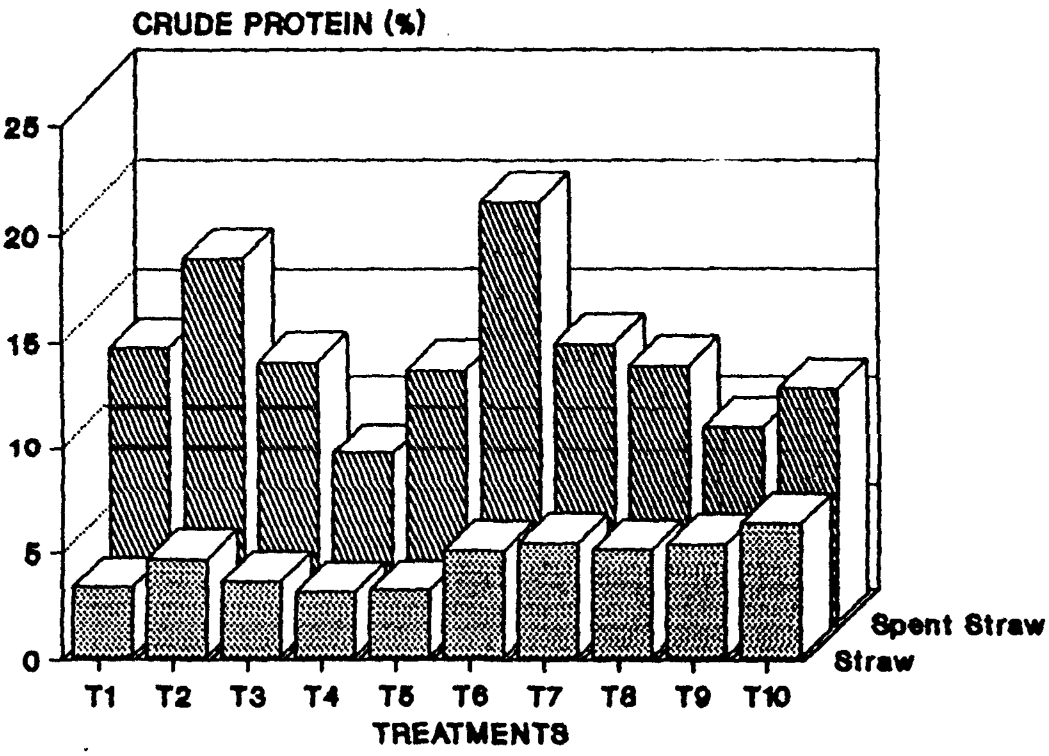

FIG. 3. EFFECT OF MUSHROOM CULTIVATION ON CRUDE PROTEIN CONTENT OF DIFFERENT SUBSTRATES.

Viz., Ortaga *et al.,* (1986); Amanat *et al.,* (1987), Chawla and Kundu, (1987), Gupta and Langar, (1988), Balasubramanya and Bhatwadekar (1988). They have reported that there was increase in the crude protein content of paddy straw and groundnut hulls when used for cultivation of *Pleurotus.* Similar results were also reported by Lavie (1988), Khalon and Das (1987). Hemics and Voros(1985) reported a change in crude protein, lipid and fibre content of Maize stalk and suggested the use of spent substrate for feeding to cattle and sheep.

4.1.4 Organic carbon content

Data regarding organic carbon content of substrates before and after *Pleurotus* cultivation are presented in Table No. 7 and Fig. 4.

Organic carbon content of different substrates before cultivation of *Pleurotus* varied significantly. Highest organic carbon content of substrate was found under T1 treatment (46.13%) followed by T8 treatment (44.88%). The lowest organic carbon content of substrate was seen in respect of T7 treatment (33.92%).

The organic carbon content of different substrates after *Pleurotus* cultivation were also found to varied significantly. The highest organic carbon content of substrates was found under T8 treatment (40.82%) followed by T5 treatment (39.97%). The organic carbon content of substrates under T1 (39.79%) and T6 treatments (39.67%) were found statistically at par with each other. The lowest organic carbon content of substrate was found under T9 treatment (29.75%). Overall

Table 7. Effect of mushroom cultivation on organic carbon content of different substrates

Treatments	Organic Carbon (%)		% Increase/ Decrease
	Straw	Spent straw	
T1	46.13	39.79	-6.34
T2	42.36	38.04	-4.32
T3	35.86	30.99	-4.87
T4	40.25	36.21	-4.04
T5	40.07	39.97	-0.10
T6	42.77	39.67	-3.10
T7	33.92	30.45	-3.47
T8	44.88	40.82	-4.06
T9	35.22	29.75	-5.47
T10	44.61	37.74	-6.87
S.E. ±	0.05	0.05	
C.D. at 5%	0.16	0.14	

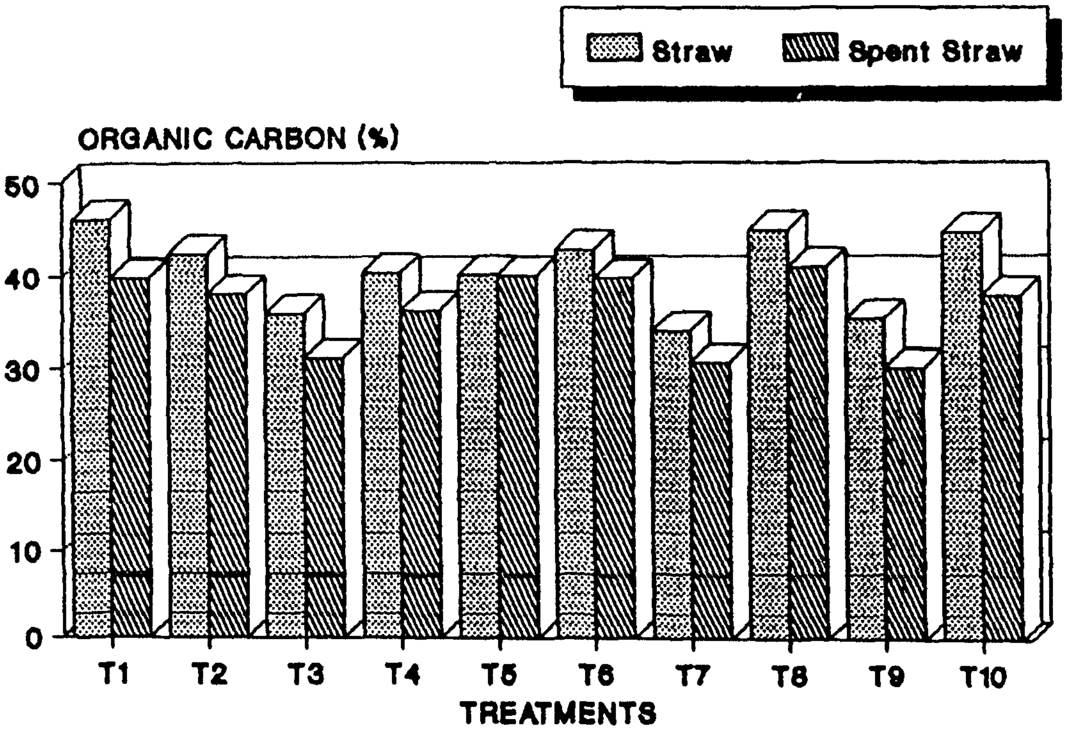

FIG. 4. EFFECT OF MUSHROOM CULTIVATION ON ORGANIC CARBON CONTENT OF DIFFERENT SUBSTRATES.

reduction in organic carbon content of different straws varied significantly due to *Pleurotus* cultivation.

The highest reduction in organic carbon content of substrates under study due to *Pleurotus* cultivation was found under T10 treatment (44.61 to 37.74%) followed by T1 treatment (46.13 to 39.79 %) while the lowest reduction in organic carbon was observed in respect of T5 treatment (40.07 to 39.97%). Similar findings regarding reduction in organic carbon content of straws were reported by Bisaria *et al.,* (1987). They have reported decrease in organic carbon content of different straws. Loss in organic carbon content of straws was due to loss of carbon in the form of carbon dioxide produced during respiratory activity of *P. sajor caju*. Similar results were also reported by Prabhu Desai *et al.,* (1991) and Thilagavathy *et al.,* (1991) in the cultivation mushroom.

4.1.5 C:N ratio

Data on the effect of mushroom cultivation on C:N ratio of substrates are presented in Table 8 and Fig. 5.

Data indicated that the C:N ratio of different substrates before *Pleurotus* cultivation varied significantly. The highest C:N ratio of substrate before *Pleurotus* cultivation was found under T5 (88.16), T1 (88.15) and T4 (82.10) treatments which were statistically at par with each other. The C:N ratio of straws under in T3 (62.93), T2 (57.77) and T8 (54.75) treatments was also found statistically at par with each other. The lowest C:N ratio of straws was observed in respect of T7 treatment (39.29).

Table 8. Effect of mushroom cultivation on C:N ratio of different substrates.

Treatments	C : N Ratio		Increase/ Decrease
	Straw	Spent straw	
T1	88.15	19.31	-68.84
T2	57.77	13.95	-43.82
T3	62.93	15.86	-47.07
T4	82.10	28.89	-53.21
T5	88.16	21.14	-67.02
T6	46.58	12.63	-33.95
T7	39.29	14.56	-24.73
T8	54.75	21.18	-33.57
T9	41.30	20.28	-21.02
T10	43.77	23.26	-20.51
S.E. ±	2.37	0.15	
C.D. at 5%	7.00	0.45	

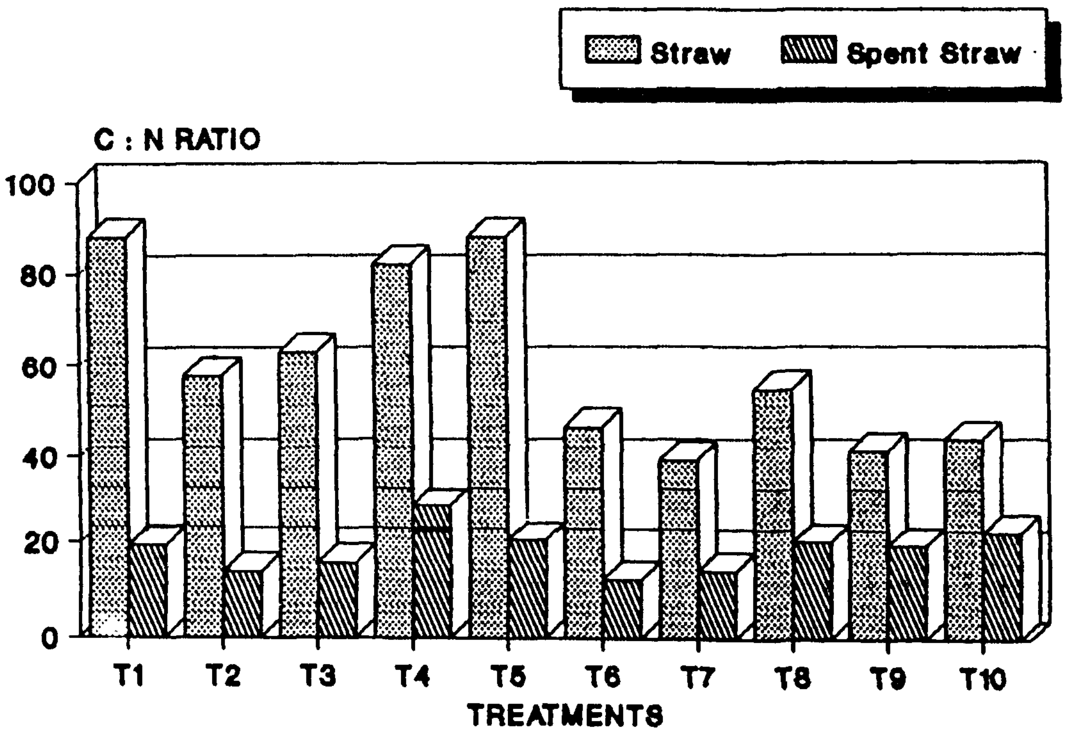

FIG. 5. EFFECT OF MUSHROOM CULTIVATION ON C:N RATIO OF DIFFERENT SUBSTRATES.

There was marked reduction in C:N ratio of different straws due to *Pleurotus* cultivation. The C:N ratio of different straws varied significantly. The highest C:N ratio of substrate after *Pleurotus* cultivation was seen in T4 (28.89) followed by T10 (23.26) T8 (21.18) and T5 (21.14) which are statistically on par with each other. The lowest C:N ratio of substrates was seen in respect of T6 (12.63).

Overall highest reduction in C:N ratio of substrates due to *Pleurotus* cultivation was seen in T1 treatment (88.15 to 19.31) followed by T5 treatment (88.16 to 21.14).

Similar observations were reported by Bisaria *et al.*, (1987). Similar findings were also found by Prabhu Desai *et al.*, (1991) on reduction in carbon content and increase in nitrogen content. of substrates. These results are also in accordance with those reported by Thilagavathy *et al.*, (1991) and Theradimani and Marimuthu (1991). They reported that the C:N ratio of coir pith was narrowed down due to cultivation of of *P. platypus* and it could be used for composting.

4.2 Mineral matter content

Data regarding the mineral matter content of different substrates before and after cultivation of *Pleurotus* are presented in the Table 9 and Fig. 6.

It would be seen from the data Table 9 that the mineral matter content of different substrates differed significantly before and after used for cultivation. Highest mineral matter content of substrates before cultivation of *Pleurotus* was found in T7 treatment (15.52%) followed by T3 treatment (15.45%), T4

Table 9. Effect of mushroom cultivation on mineral matter content of different substrates.

Treatments	Mineral matter (%)		% Increase/ Decrease
	Straw	Spent straw	
T1	8.30	7.40	-0.90
T2	9.4	8.45	-0.95
T3	15.45	11.61	-3.84
T4	14.45	12.25	-2.20
T5	10.52	9.63	-0.89
T6	9.84	7.13	-2.71
T7	15.52	13.06	-2.46
T8	6.69	8.43	1.74
T9	12.93	11.56	-1.37
T10	10.51	8.42	-2.09
S.E. ±	0.09	0.07	
C.D. at 5%	0.027	0.023	

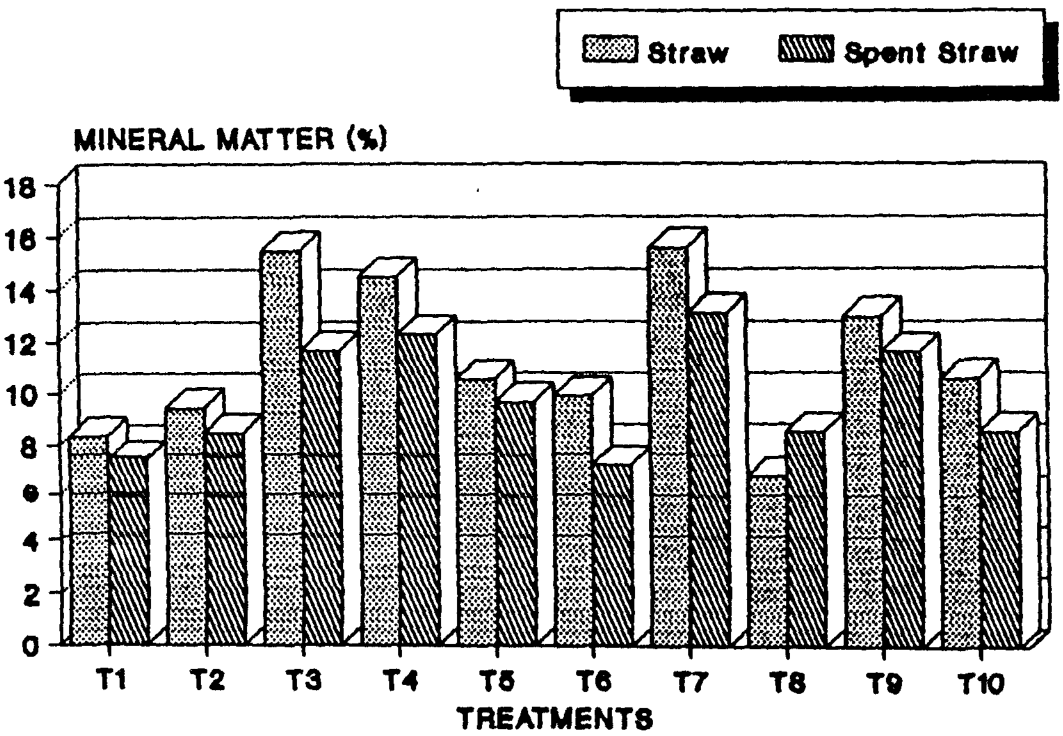

FIG. 6. EFFECT OF MUSHROOM CULTIVATION ON MINERAL MATTER CONTENT OF DIFFERENT SUBSTRATES.

treatment (14.45%). The mineral matter content of substrates under treatment T5 (10.52%) and T10 (10.51%) was found at par with each other. The lowest mineral matter content of substrates was recorded in respect of T8 treatment (6.69%).

Data presented in Table 4 revealed that there was decrease in mineral matter content of different straws used for the cultivation of *P. sajor-caju*.

The highest reduction in mineral matter was found in respect of T3 treatment (15.45 to 11.61 %) followed by T4 treatment (14.45 to 12.25 %). The reduction of mineral matter content of straws under T3 and T9 treatments was found at par with each other. Similar results were reported by Bisaria *et al.*, (1987).

4.2.1 Calcium content

Data regarding effect of mushroom cultivation on calcium content of straws are presented in Table 10 and Fig. 7. It would be promulgated from data in (Table 10) that calcium content of different straws before mushroom cultivation varied significantly. The highest calcium content of straw was found under T4 treatment (392.63 mg $100g^{-1}$) followed by T2 (328.51 mg $100g^{1}$) and T9 (313.63 mg $100g^{-1}$) which was statistically at par with each other. The calcium content in respect of treatments T7, T10 and T8 were found statistically on par with each other. The lowest calcium content of straw was seen in respect of T3 treatment (215.83 mg $100g^{-1}$)

It can be seen from the data presented in Table 10 that the calcium content of different straw increased when they were used for cultivation of *P. sajor-caju*. The increase in calcium

Table 10. Effect of mushroom cultivation on calcium content of different substrates mg 100 g^{-1}).

Treatments	Calcium (mg 100^{-1})		Increase/ Decrease
	Straw	Spent straw	
T1	248.06	273.40	+ 25.34
T2	328.51	382.50	+ 53.99
T3	215.83	268.73	+ 52.90
T4	392.63	421.75	+ 29.12
T5	261.60	321.93	+ 60.33
T6	247.10	281.03	+ 33.93
T7	285.56	307.06	+ 21.50
T8	268.13	277.03	+ 8.90
T9	313.63	337.60	+ 23.97
T10	275.61	283.49	+ 7.88
S.E. ±	6.65	8.65	
C.D. at 5%	19.62	25.52	

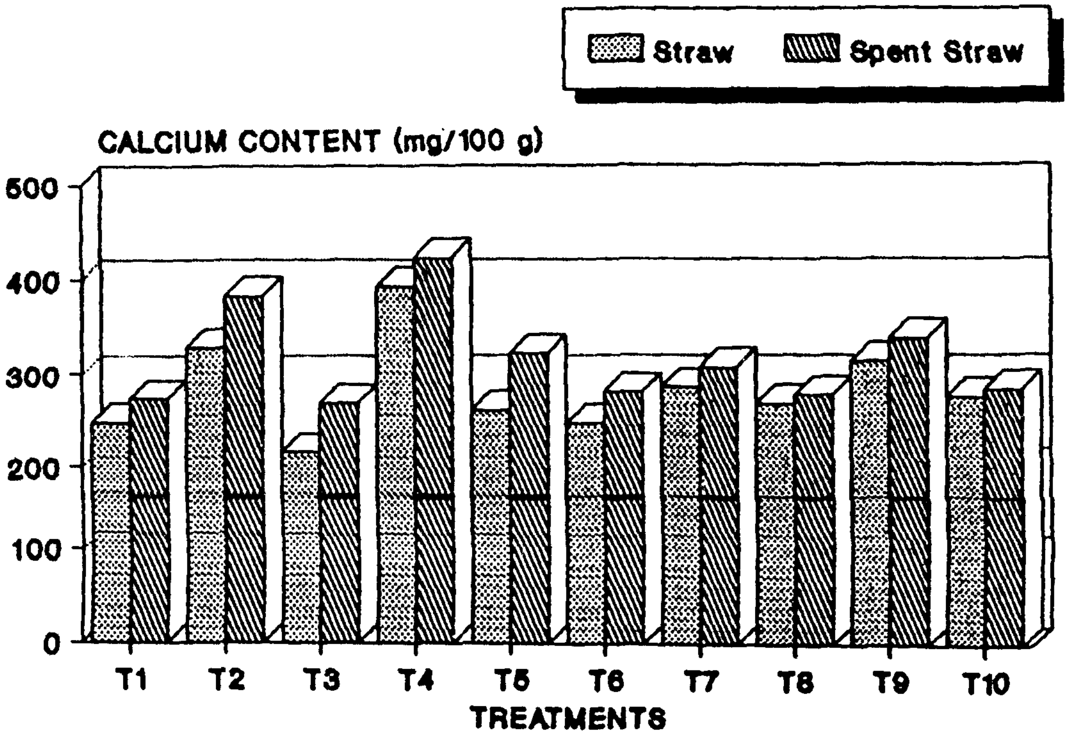

FIG. 7. EFFECT OF MUSHROOM CULTIVATION ON Ca CONTENT OF DIFFERENT SUBSTRATES.

content of straw was seen significantly highest in T4 treatment (421.75 mg 100g^{-1}) followed by T2 (382.50 mg 100g^{-1}). However the increase in calcium content of straws under T9 and T5 treatments was statistically at par with each other and those under T10, T6, T8, T1 and T3 treatments were also found statistically at par with each other. Similar observations on calcium content of straws were also reported by Bisaria *et al.,* (1987).

4.2.2 Phosphorous content

Data regarding P content of straw before cultivation of *P. sajor-caju* are presented in Table 11 and Fig. 8. The P content of different substrates before cultivation of mushroom was found in the range of 76.44 - 164.66 mg 100g^{-1} . Highest P content of substrate was recorded in respect of T4 (164.66 mg 100g^{-1}) followed by T9 (116.63 mg 100g^{-1}), T7 (133.06 mg 100g^{-1}), T5 (112.06 mg 100g^{-1}) and T2 (107.01 mg 100g^{-1}) which were statistically at par with each other. However the remaining treatments T8, T10, T3 and T1 were also found statistically at par with each other.

The P content of spent straw was increased in all treatments. The P content of spent straw was noticed highest in respect of T4 treatment (175.66 mg 100g^{-1}) followed by T5 treatment (138.00 mg 100g^{-1}). The phosphorous content of T9, T1, T7 and T2 treatments were found at par with each other. However the P content of spent straw in respect of T3, T6 and T8 treatments were seen to be on par with each other. The lowest P concentration in spent straw was found in respect of T8 and T10 treatments which were statistically at par with each other.

Table 11. Effect of mushroom cultivation on phosphorous content of different substrates (mg $100g^{-1}$).

Treatments	P (mg 100^{-1})		Increase/ Decrease
	Straw	Spent straw	
T1	76.44	120.90	+ 44.46
T2	107.01	111.37	+ 4.36
T3	77.67	104.18	+ 26.51
T4	164.66	175.66	+ 11.00
T5	112.06	138.00	+ 25.94
T6	96.71	103.05	+ 6.34
T7	113.06	120.63	+ 7.57
T8	82.77	91.39	+ 8.62
T9	116.63	122.60	+ 5.97
T10	79.03	85.73	+ 6.70
S.E. ±	4.13	4.42	
C.D. at 5%	12.18	13.03	

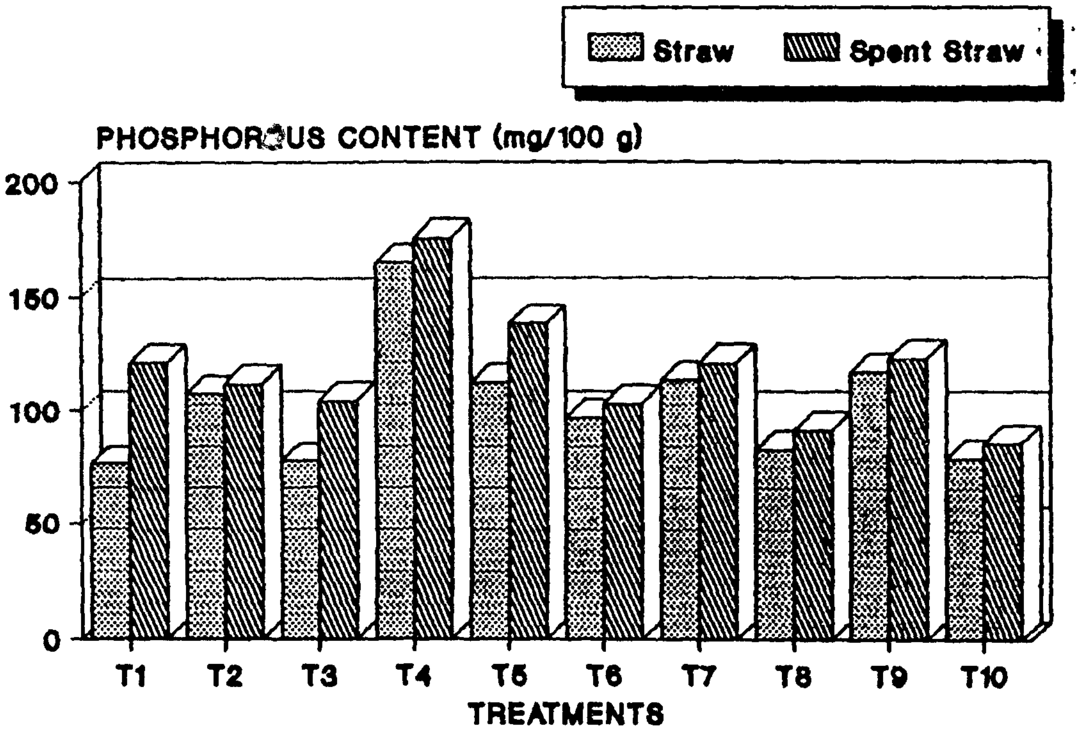

FIG. 8. EFFECT OF MUSHROOM CULTIVATION ON P CONTENT OF DIFFERENT SUBSTRATES.

It is evident from the data the P content of spent straws was increased with the cultivation of *P. sajor-caju*. The increase in P content of spent straw was more prominant in wheat straw, bajra stalks and leaves and Jowar stalks and leaves. Similar results were found by Bisaria *et al.,* (1987).

4.2.3 pH

Data on the pH of different straws as influenced by the cultivation of *P. sajor-caju* during cropping period of 50 days. are presented in Table 12. It is evident from the data (Table 12. and Fig. 9) that pH of different substrates varied significantly in all the treatments. The highest pH values for substrates were obtained in respect of T2 (7.11), T9 (7.03) and T10 (6.71) treatments and found statistically at par with each other. However, the pH of substrates under T10,T8 treatments were also found statistically at par with each other while the lowest pH value was obtained in respect of T5 treatment (5.12).

The pH of different spent straws was found increased significantly. The highest pH of spent straw was seen in respect of T6 treatment (8.00) followed by T2 and T10 which were at par with each other. However, the pH of straws under T1 and T9 treatments was also seen at par with each other. Similarly the pH of straws under T4, T3 and T6 treatments was also found at par with each other.

Table 12. Effect of mushroom cultivation on pH of different substrates.

Treatments	pH		Increase/ Decrease
	Straw	Spent straw	
T1	7.02	7.60	+ 0.58
T2	7.11	7.91	+ 0.80
T3	5.37	5.92	+ 0.55
T4	5.32	5.99	+ 0.67
T5	5.12	5.84	+ 0.72
T6	6.92	8.00	+ 1.08
T7	6.50	7.09	+ 0.59
T8	6.70	7.11	+ 0.41
T9	7.03	7.49	+ 0.46
T10	6.71	7.85	+ 1.14
S.E. ±	0.06	0.11	
C.D. at 5%	0.18	0.31	

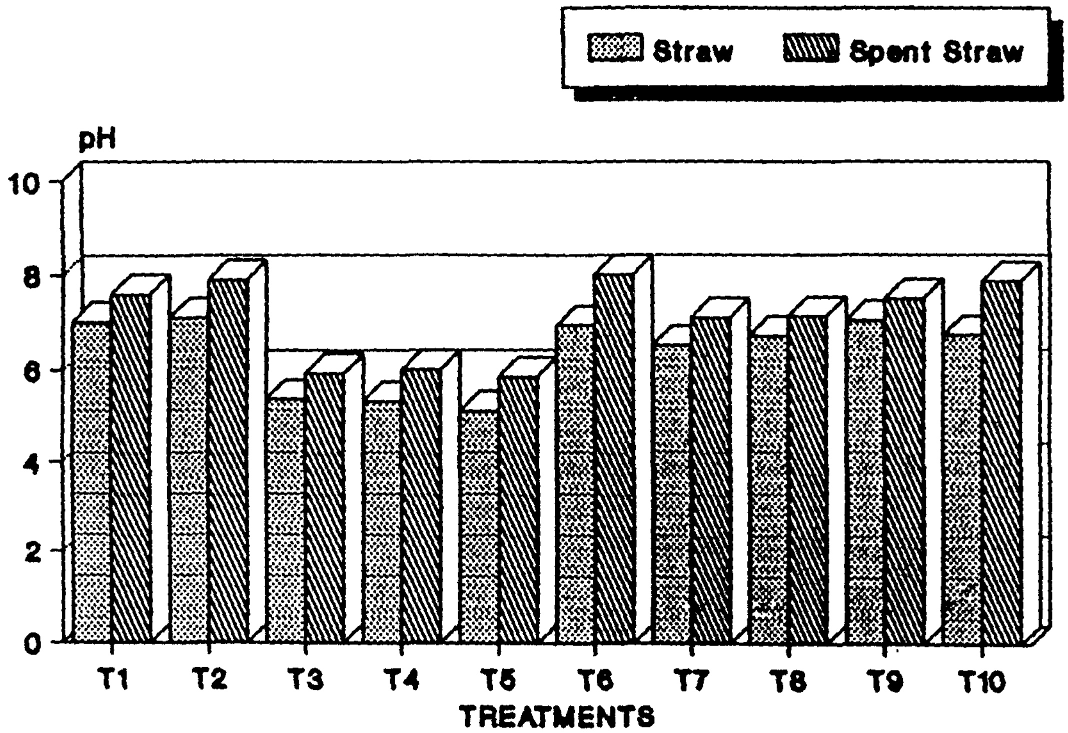

FIG. 9. EFFECT OF MUSHROOM CULTIVATION ON pH OF DIFFERENT SUBSTRATES.

4.3 Effect of different substrates on stipe length, pileus size, and days required for first flush

Data pertaining to the stipe length, pileus size and days required for first flush of *P. sajor caju* as influenced by different substrates are given in the Table. 13 and Fig.10.

4.3.1 Stipe length

It would be seen from the data (Table 13) that stipe length of *P. sajor-caju* was influenced significantly according by different substrates. The stipe length of different fruit bodies grown on different substrates were found in the range of (2.26 to 3.56 cm). The highest stipe length (3.56 cm) of mushroom fruit body was obtained in respect of soybean straw + wheat straw (T9) The stipe length of mushroom in respect of T7 (3.29 cm), T5 (3.17 cm) and T2 (3.16 cm) treatments were found statistically at par with each other. However, the stipe length of mushroom cultivated on straws under T6 (3.00 cm), T3 (2.95 cm), T8 (2.83 cm) were also found statistically on par with each other.

4.3.2 Pileus size

It would be seen from the data presented in Table 13. and Fig.10 that the pileus size of *P. sajor-caju*, significantly varied due to different substrates used. The pileus size of mushroom fruit bodies under different substrates ranged between 21.32 cm^2 to 29.38 cm^2 . The highest pileus size of mushroom fruit bodies was observed under T3 (29.40 cm^2) and T5 (29.38 cm^2) which were statistically at par with each other followed by T2 (28.51 cm^2) and T8 (28.21 cm^2) which were also statistically at par with each other. The lowest piles size of mushroom fruit body was obtained in T10 treatment in respect of (21.32 cm^2).

Table 13. Effect of different substrates on stipe length, pileus size and days required for first flush

Treatments	Stipe length (cm)	Pileus Size (cm2)	Days required for first flush
T1	2.26	24.50	20.66
T2	3.16	28.51	20.33
T3	2.95	29.40	22.66
T4	2.54	27.05	22.66
T5	3.17	29.38	23.00
T6	3.00	25.68	25.00
T7	3.29	27.80	22.66
T8	2.83	28.21	26.66
T9	3.56	28.88	21.00
T10	2.64	21.32	25.66
S.E. ±	0.08	0.12	0.62
C.D. at 5%	0.23	0.36	1.84

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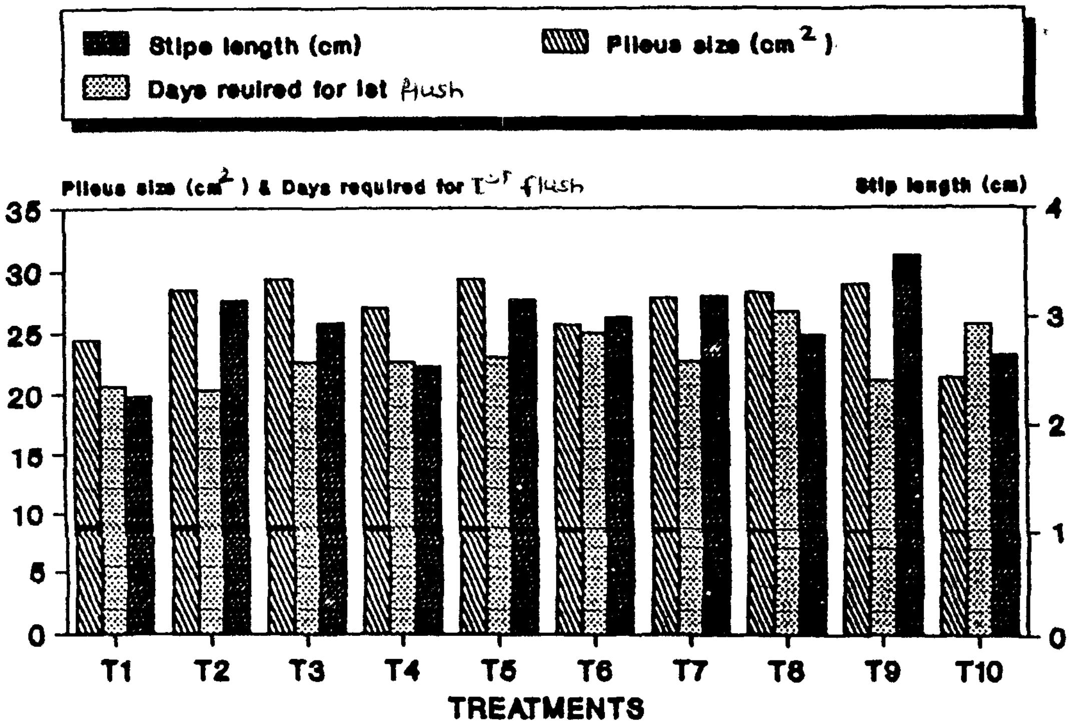

FIG. 10. EFFECT OF DIFFERENT SUBSTRATES ON STIPE LENGTH, PILEUS SIZE AND DAYS REQUIRED FOR FIRST FLUSH OF MUSHROOM.

4.3.3 Days required for first flush

Data on the days required for first flush mushroom bodies as influenced by different substrates, are presented in Table 13 and Fig. 10. Significantly more days were required for first flush of mushroom cultivated on the straw under treatment T8 (26.66) and T10 (25.66) which are statistically at par with each other. However the days required for the the first flush under the treatments T5, T4, T3 and T7 were found statistically at par with each other. Similar findings were also reported by Thilagavathy *et al.*, (1991).

4.4 Effect of different substrates on number of sporophore, weight of sporophore, yield and biological efficiency of mushroom.

4.4.1 Number of sporophore

Data presented on number of sporophore and weight of sporophore as influenced by different substrates are presented in Table 14, Fig. 11 A. Data revealed that the number of sporophore under different substrates were ranged between 101.66 to 178.33. Highest number of sporophores were noticed in respect of T6 treatment (178.33) and T2 (171.33), and they were statistically at par with each other. While the no. of sporophores in respect of T5, T1 and T7 treatments were also found statistically at par with each other. The lowest number of sporophore were found in respect of T10 treatment (101.66). Sharma (1983) reported that average weight of sporophore was also increased with the rise in moisture content of the substrate.

Table 14. Effect of different substrates on number of sporophore, weight of sporophore, yield and biological efficiency of mushroom.

Treatments	Number of sporophore	Weight of sporophore (g)	Yield ($g\,kg^{-1}$ of straw)	Biological efficiency (%)
T1	164.66	4.06	668.30	66.83
T2	171.33	4.65	796.27	79.62
T3	154.66	3.50	541.97	54.19
T4	136.33	2.61	357.05	35.70
T5	165.33	3.75	612.96	61.29
T6	178.33	5.12	914.03	91.40
T7	161.00	3.47	556.83	55.68
T8	134.00	2.49	333.12	33.31
T9	146.33	3.47	507.89	50.78
T10	101.66	2.53	257.75	25.77
S.E. ±	2.94	0.05	9.11	0.91
C.D. at 5%	8.66	0.15	26.88	2.70

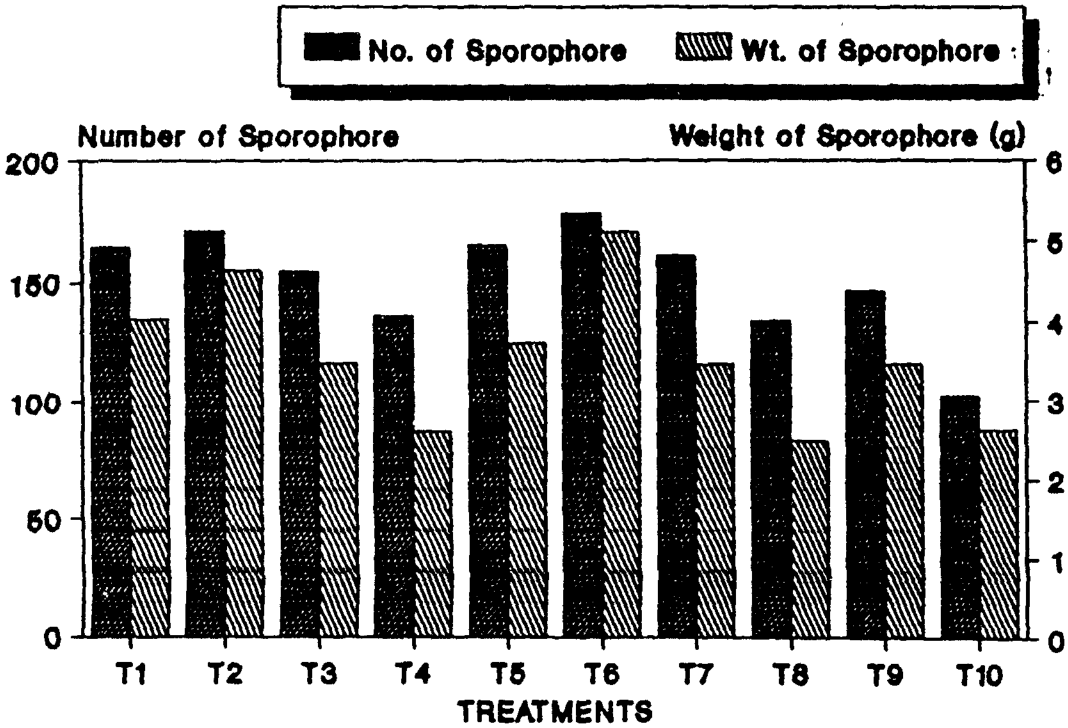

FIG. 11 A. EFFECT OF DIFFERENT SUBSTRATES ON NUMBER AND WEIGHT OF SPOROPHORE OF MUSHROOM.

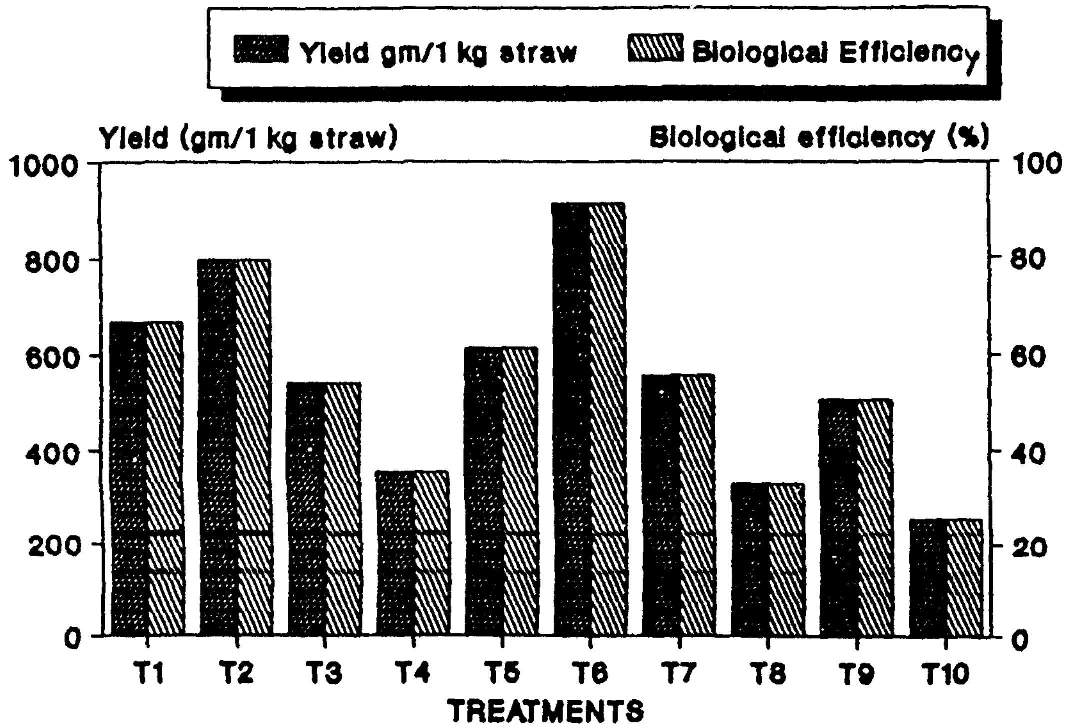

FIG. 11 B. EFFECT OF DIFFERENT SUBSTRATES ON YIELD AND BIOLOGICAL EFFICIENCY OF MUSHROOM.

4.4.2 Weight of sporophore

Data on the weight of sporophore as influenced by the different substrates are given in Table 14 and Fig.11 A. The highest weight of sporophore was found in the respect of treatment T6 (5.12 g) followed by T2 (4.65 g). The weight of sporophore under T3, T7 and T9 treatments were found statistically at par with each other, while lowest weight of sporophore was recorded in respects of T8 treatment (2.49 g).

4.4.3 Yield and biological efficiency

Data regarding to the yield of fresh mushrooms significantly influenced by the different substrates are presented in Table 14 and Fig. 11 B.

It would be seen from the Table 14. that significantly highest yield of mushroom was observed in respect of T6 treatment (914.03 g Kg^{-1} of straw) and having biological efficiency (91.40%) followed by T2 treatment (796.27 g Kg^{-1} of straw) with biological efficiency (79.62 %). The mushroom yield obtained under T1 treatment (668.33 g Kg^{-1} of straw) and biological efficiency (66.83%). The mushroom yield in case of T7 and T3 treatments were found statistically at par with each other. The lowest yield of mushroom was noticed in T10 treatment (257.75 g Kg^{-1} of straw) and biological efficiency (25.77%). Similar results were reported by several workers. Poo chow (1980) reported superiority of cotton waste over paddy straw. Platt *et al.,* (1982), Lavie (1988), Silankove *et al.,* (1988), Leong (1980). Patil *et al.,* (1989) also reported superiority of cotton waste over jowar stalks and leaves and wheat straw. These results are in accordance with Veena Savalgi *et al.,* (1991), Patil *et al.,* (1991). Low yield of mushroom obtained when groundnut creepers used for cultivation of mushroom (Veena Savalgi, 1991). Superiority of paddy straw over wheat straw also reported by Zakia and Shrivastava (1962), Shin *et al.,* (1971), Goh and Graham (1975), Bano *et al.,* (1979), Khanna and Garcha (1982), Bisaria *et al.,* (1987), Ramesh and Ansari (1987).

Shivaprakasam et *al.,* (1987) noticed the higher yield of mushroom cultivation on paddy straw. Rajarathnam *et al.,* (1990) reported higher yield of mushroom cultivated on paddy straw with cotton seed. The results are in accordance with Prabhu Desai *et al.,* (1991).

4.5 Effect of different substrates on proximate composition of mushroom (*P. sajor-caju*)

4.5.1 Moisture

Data presented in Table 15 and Fig. 12 revealed that the differences in moisture content of fruit bodies of mushroom cultivated on different substrates were not significant. The moisture content of mushroom fruit bodies were found in the range of (89.98 to 91.61%), however the highest moisture content was observed in respect of T6 treatment followed by T9 and T8. The lowest moisture content was found in fruit bodies in case of T1 treatment. These results were in accordance with the finding of Bisaria *et al.,* (1987). They reported the moisture content of fruit bodies of *P. sajor-caju* ranged between 88.94 to 92.65% . Similar results were also obtained by Thilagavathy *et al* (1991).

Table 15. Effect of different substrates on proximate composition of P. Sajor-caju (fresh weight basis)

Treatments	Moisture	Dry matter	Crude protein	Carbohydrate	Fat	Crude fibre	Mineral matter
	<------------------------------			(%)			------------------------------>
T1	89.98	10.02	3.34	4.66	0.59	1.10	0.72
T2	90.50	9.50	3.51	4.06	0.21	1.07	0.64
T3	91.14	8.86	3.26	4.08	0.17	0.92	0.42
T4	91.13	8.87	3.59	3.83	0.19	0.90	0.35
T5	90.89	9.11	3.47	4.00	0.21	1.00	0.41
T6	91.61	8.39	3.62	3.11	0.13	1.13	0.38
T7	90.46	9.54	3.57	3.95	0.24	1.12	0.71
T8	90.38	8.62	3.36	3.27	0.21	1.02	0.54
T9	91.59	8.41	3.31	3.50	0.21	1.00	0.38
T10	90.50	9.50	3.54	3.54	0.22	1.12	1.06
S.E. ±	0.39	0.38	1.13	0.11	0.016	0.036	0.13
C.D. at 5%	N.S.	N.S.	N.S.	0.32	0.056	0.108	0.38

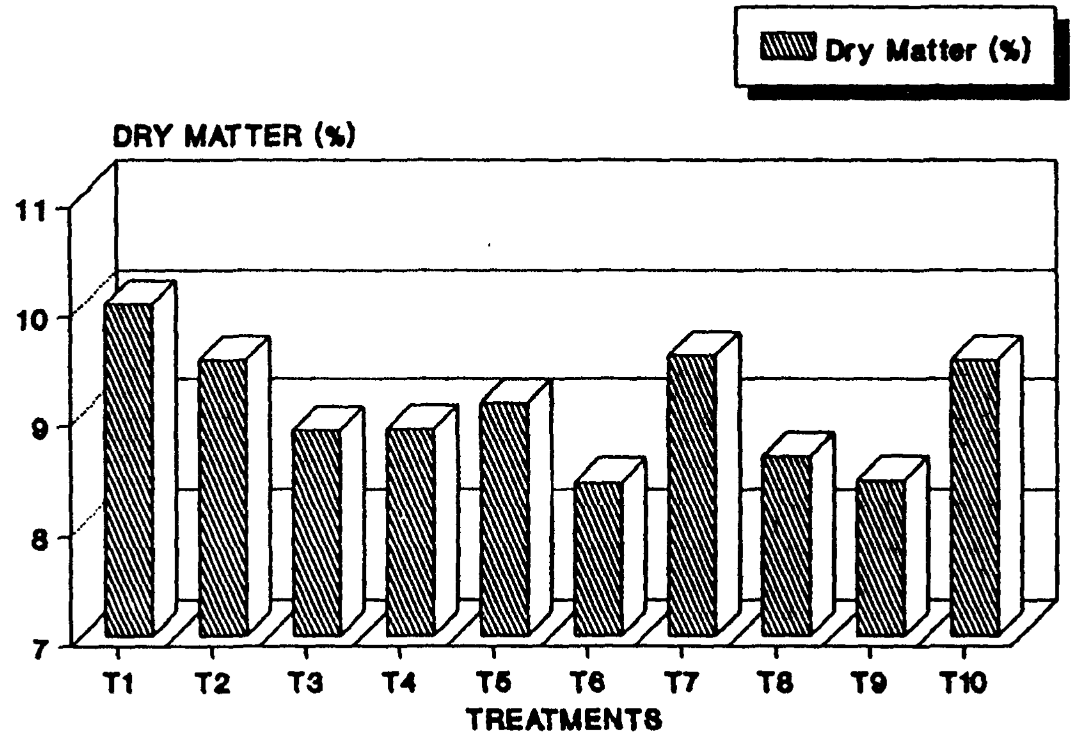

FIG. 12 A. EFFECT OF DIFFERENT SUBSTRATES ON DRY MATTER CONTENT OF MUSHROOM.

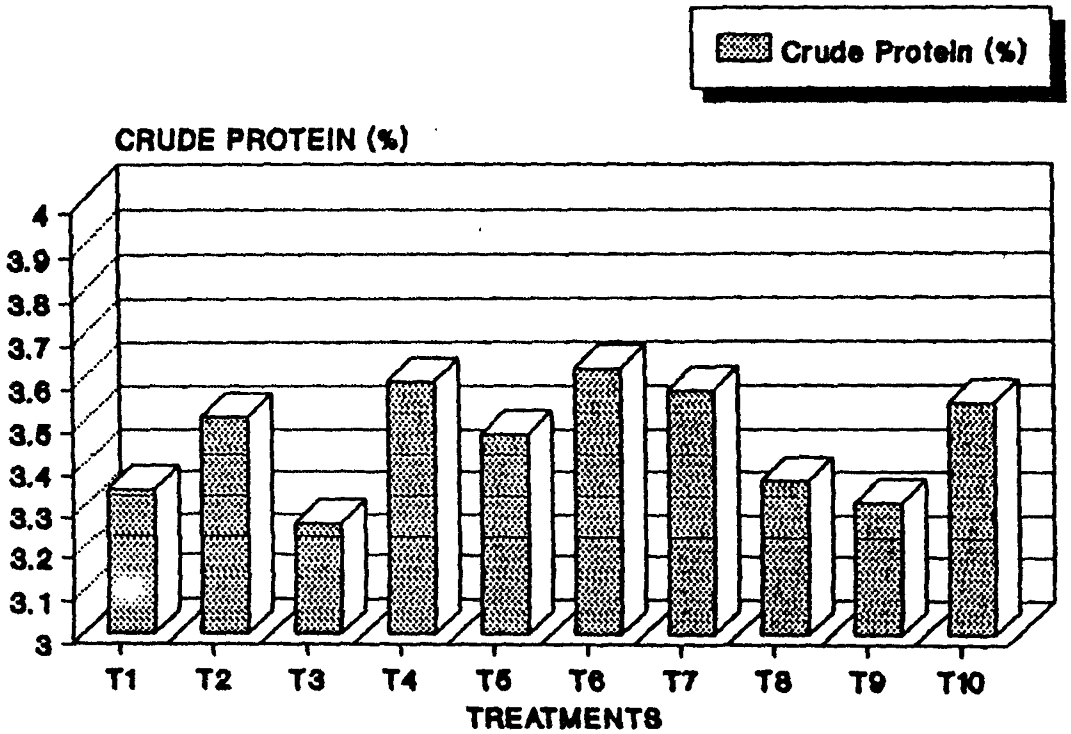

FIG. 12 B. EFFECT OF DIFFERENT SUBSTRATES ON CRUDE PROTEIN CONTENT OF MUSHROOM.

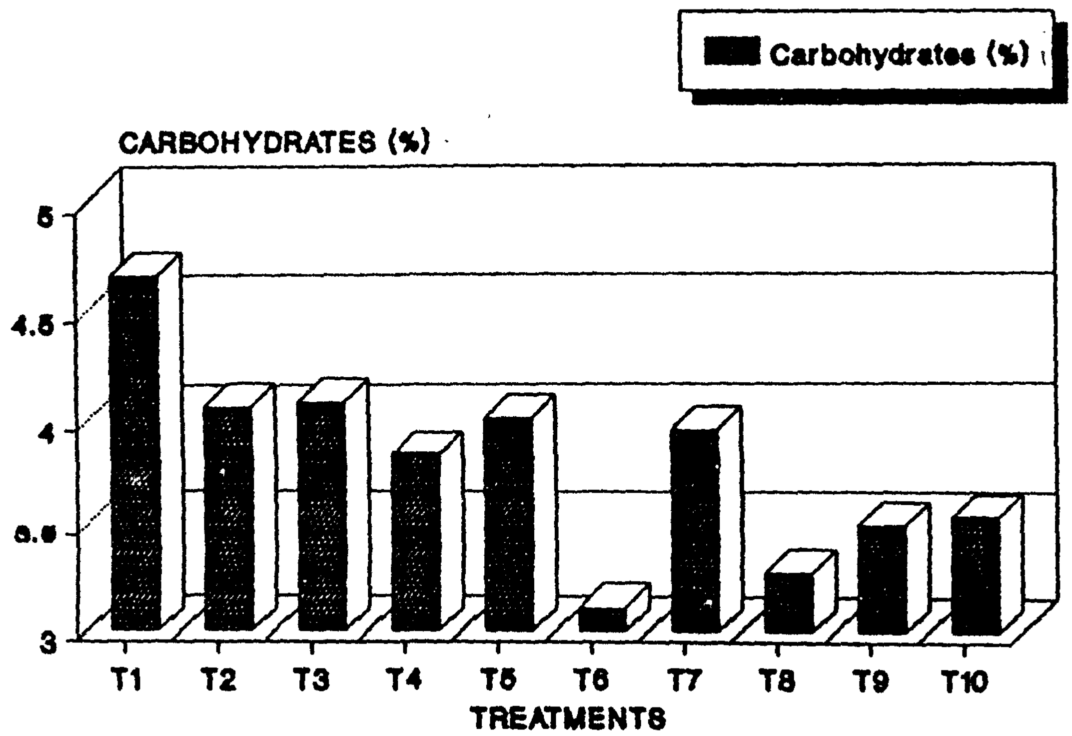

FIG. 12 C. EFFECT OF DIFFERENT SUBSTRATES ON CARBOHYDRATES CONTENT OF MUSHROOM

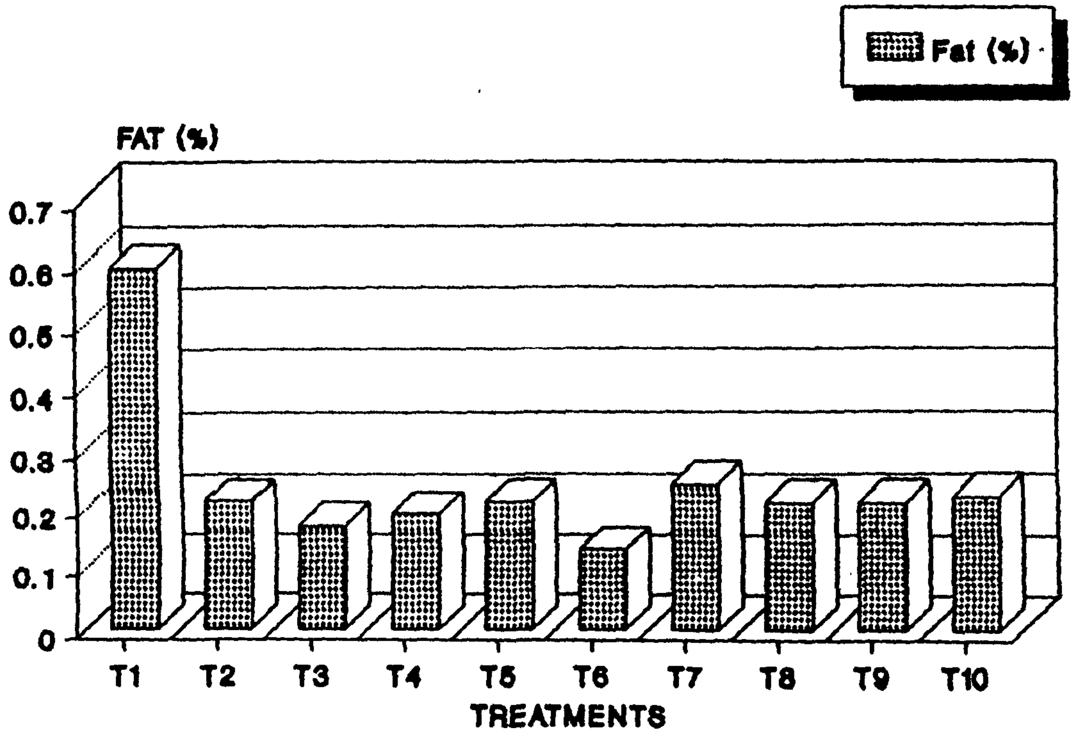

FIG. 12 D. EFFECT OF DIFFERENT SUBSTRATES ON FAT CONTENT OF MUSHROOM.

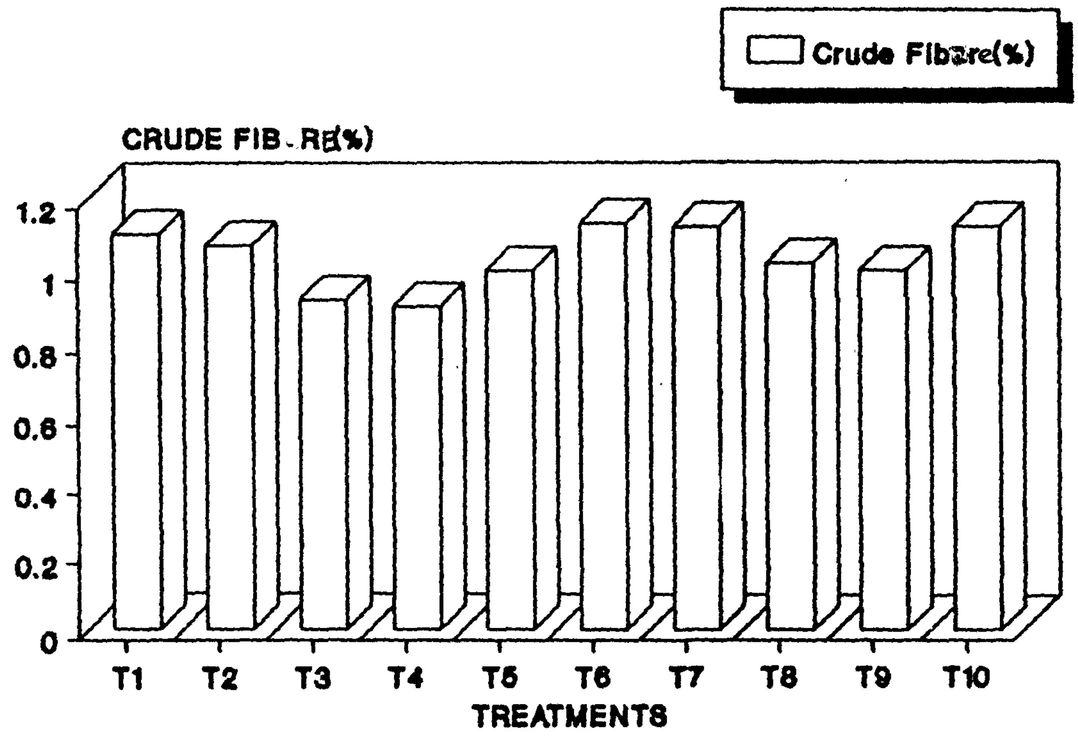

FIG. 12 E. EFFECT OF DIFFERENT SUBSTRATES ON CRUDE FIBRE CONTENT OF MUSHROOM.

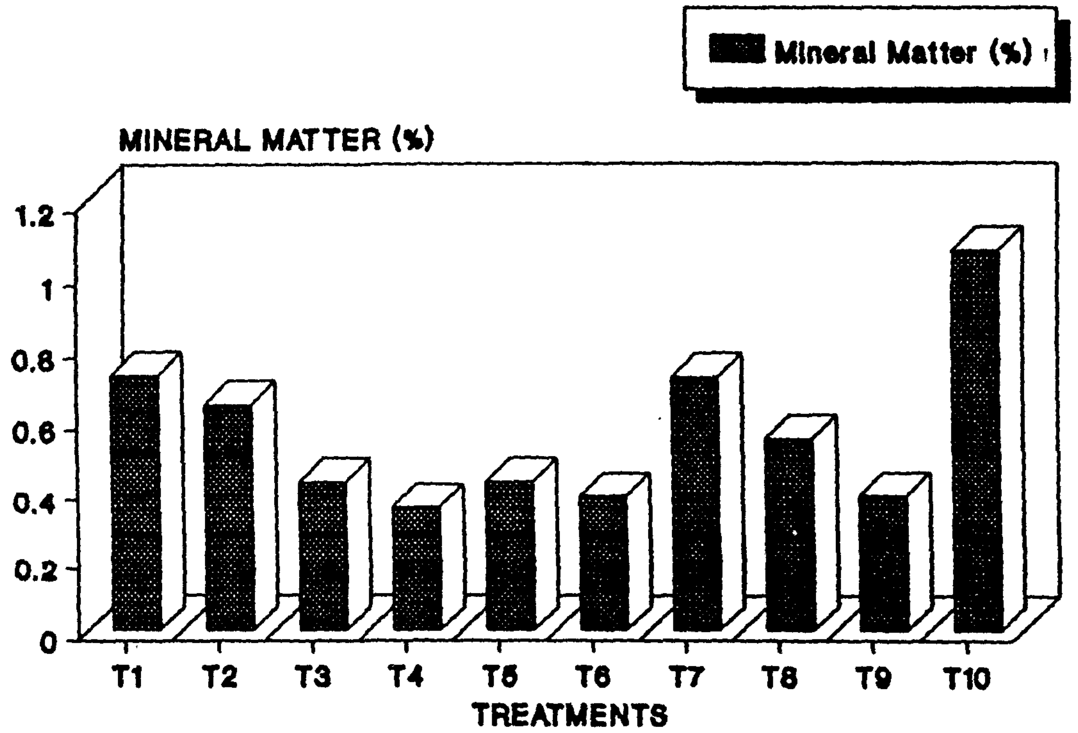

FIG. 12 F. EFFECT OF DIFFERENT SUBSTRATES ON MINERAL MATTER CONTENT OF MUSHROOM.

4.5.2 Dry matter

Data on dry matter content of fruit bodies of *P. sajor-caju* as influenced by different substrates are presented in Table. 15 and Fig. 12 A. It would be seen from the data that dry matter content of fruit bodies of *P. sajor-caju* was found to be non significant. However the highest dry matter content was seen in the fruit bodies of under the treatment T1 (10.02 %) followed by T2 (9.5 %) and T10 (9.50 %). The lowest value of dry matter of fruit bodies of mushroom was obtained in respect of T6 treatment (8.39). Similar results were also reported by Bisaria *et al* (1987), Khanna and Garcha (1986), Rai and Sexena (1988), Mostafa *et al.,* (1991).

4.5.3 Crude Protein

Proteins are the chief constituents of cell and form an important component of muscles, tissues and vital fluid of blood. They supply building material for the body and make good the wear and tear of the tissue. The food rich in protein is often called as "Body Building foods". Thus protein is one of the important nutrient in the food. The n utritional quality of protein depend on the amino acid composition. Most of the mushrooms are fair source of protein with good composition of essential amino acid (Gopalan, 1980).

Data on protein content of mushroom fruit bodies as influenced by various substrates are presented in Table 15 and Fig. 12 B. It would be seen from the data presented in Table 15 that protein content of mushroom found to be non significant when pleurotus grown on different substrates. However the crude protein content of fruit bodies of pleurotus was found to be highest on cotton stalks (3.62 %), which was statistically found to be at par with *Pleurotus* grown on soybean straw (3.57%). The lowest value of crude protein was obtained in the fruit bodies of mushroom when they were cultivated on bajra stalks and leaves (3.26 %).

Similar results were obtained by Khanna and Garcha (1984), Bisaria *et al.,* (1991), Rai *et al.*, (1988), Mostafa *et al.,* (1991), Thilagavathy *et al.,* (1991). Khanna and Garcha reported that *Pleurotus Sajor-Caju* contains 26.94 % protein on dry weight basis. These findings are similar to Bisaria *et al.,* (1987) as reported that protein content of *P. sajor-caju* was 9.8% on fresh weight basis.

4.5.4 Carbohydrates

Plant carbohydrates make up to about 70 % of the total weight of nutrients in the diet of man and omnivorous animals. Carbohydrates are the least expensive source of calories in diet. However low carbohydrate diet is essential for diabetic patient, mushrooms being poor source of carbohydrates are useful in diabetic diet. The carbohydrate content of fruit bodies as influenced by different substrate are presented in Table. 15 and Fig. 12 C.

It would be seen from the data, that the carbohydrate content in fruit bodies varied significantly due to different substrates. The highest carbohydrate content was noted in fruit bodies under treatment T1 (4.66%). The carbohydrate content of fruit bodies obtained from the treatments T3 (4.08%), T2 (4.06%), T5 (4.00%), T7 (3.95%) and T4 (3.83%) were found statistically on par with each other. However the carbohydrate content of mushroom obtained from T10, T9 and T8 treatments were also statistically at par with each other. While the lowest carbohydrate content of fruit bodies was observed in respect of in T6 treatment (3.11%). Similar results were reported by Bano and Rajarathnam (1982) Bisaria *et al.*, (1987). They reported that the carbohydrate content of fruit bodies grown on wheat straw was found higher than those grown on paddy straw, jowar straw, maize straw and bajra straw. Similar observations were also noticed by Rai *et al.*, (1988), Mostafa *et al.*, (1991).

4.5.5 Fat

Like protein fat is an essential ingredient in diet. Fat is useful to the body in number of ways. It is concentrated source of energy and supplies more energy per unit weight than any other either protein or carbohydrates. The fat content of mushroom was found to be low. A diet low in fat is useful to reduce blood cholesterol level and mushroom serve this purpose as a protective food.

Data on fat content of fresh mushroom fruit bodies as influenced by the different substrates are presented in Table. 15 and Fig.12 D. It would be seen from the data the fat content of Pleurotus fruit bodies under different substrates was in the range of 0.13 - 0.24 % . Significantly high fat content of mushroom was observed in respect of T1 treatment (0.59%) while the other treatment viz. T7, T10, T8, T5, T9, T2 and T4 were found at par with each other. The lowest fat content of mushroom was observed in T6 treatment (0.13 %). Khanna and Garcha (1984) reported similar observations. Bisaria *et al.,* (1987) also reported that fat content of mushroom cultivated on different substrates varied from 1.55% to 1.80%. Rai *et al.*, (1988); Mostafa *et al.,* (1991) reported that fat content of *P. sajor-caju* was found higher than *P. florida*.

4.5.6 Crude fibre

Naturally this constituent is the least digestible part of food and provides no energy but useful in diet. Data on the crude fibre content of fresh fruit bodies of mushroom as influenced by the different substrates are presented in Table. 15 and Fig.12 E.

Crude fibre content of fruit bodies of mushroom cultivated on different substrates varied significantly and it ranged between 0.90 to 1.13% . However, highest crude fibre content of mushroom was found in respect of T6 (1.13%), T7(1.12%) and T10(1.12%) treatments and they were at par with each other. The crude fibre content of mushroom in respect of T8, T9 and T5 treatments were found more or less the same. The lowest crude-fiber content was seen in T4 treatment (0.90 %). These values were within the figures as reported by Bano *et al.,* (1981). Bisaria *et al.,* (1989); Rai *et al.,* (1988)

4.5.7 Mineral matter

It is estimated that an average man excretes daily about 20 to 30 g of mineral salts consisting mainly of chlorides, sulphates, potassium, magnesium and calcium. This output must be made good by the intake. Salts needed for the body are ingested through the food stuffs. Thus the mineral salts present in food stuffs plays an important role in the animal metabolism. Some of the mushrooms are rich in vitamins and minerals. (Gopalan,1980).

Data regarding mineral matter content of fruit bodies was found significantly varied due to different substrates (Table 15 and Fig. 12 F). The mineral matter content of fresh Pleurotus fruit bodies as influenced by different substrates were found in the range of 0.35 to 1.06% , while significantly highest mineral matter content found in respect of T10 treatment (1.06%) followed by T1 (0.72%) and T7(0.71%) treatments, which are statistically at par with each other. The mineral matter content of fruit bodies in respect of T1, T7, T2, T8, T3, T5 and T6 treatments were found at par with each other. The lowest mineral matter content of fruit bodies was found in respect of T4 treatment (0.35%) and these values of mineral matter found are in accordance with those reported by Bano *et al.*, 1981; Bisaria *et al.*, (1987) and Rai *et al.*,(1988).

4.6 Effect of different substrates on calcium, phosphorous and Iron content of mushroom (mg $100g^{-1}$)

4.6.1 Calcium

Among the different minerals, calcium occurs in the highest amount in the body. Calcium is present in the skeleton and in soft tissues. It is essential for the formation of bone, teeth, clotting of blood, contraction of heart muscles. The data regarding calcium content of mushroom is presented in Table 16. and Fig. 13.

Table 16. Effect of different substrates on calcium, phosphorous and iron content of Pleurotus sajor-caju (expressed in mg $100g^{-1}$.)

Treatments	Calcium	Phosphorous	Iron
	<----------- mg 100^{-1}	----------------	---->
T1	28.23	407.33	10.70
T2	34.5	536.76	12.33
T3	28.62	518.01	11.61
T4	41.54	607.83	7.76
T5	34.97	582.98	7.60
T6	30.29	414.06	14.23
T7	35.24	476.23	11.66
T8	35.08	426.66	13.06
T9	25.80	498.00	13.16
T10	30.89	404.43	11.76
S.E. ±	1.26	8.85	0.034
C.D. at 5%	3.70	26.11	0.102

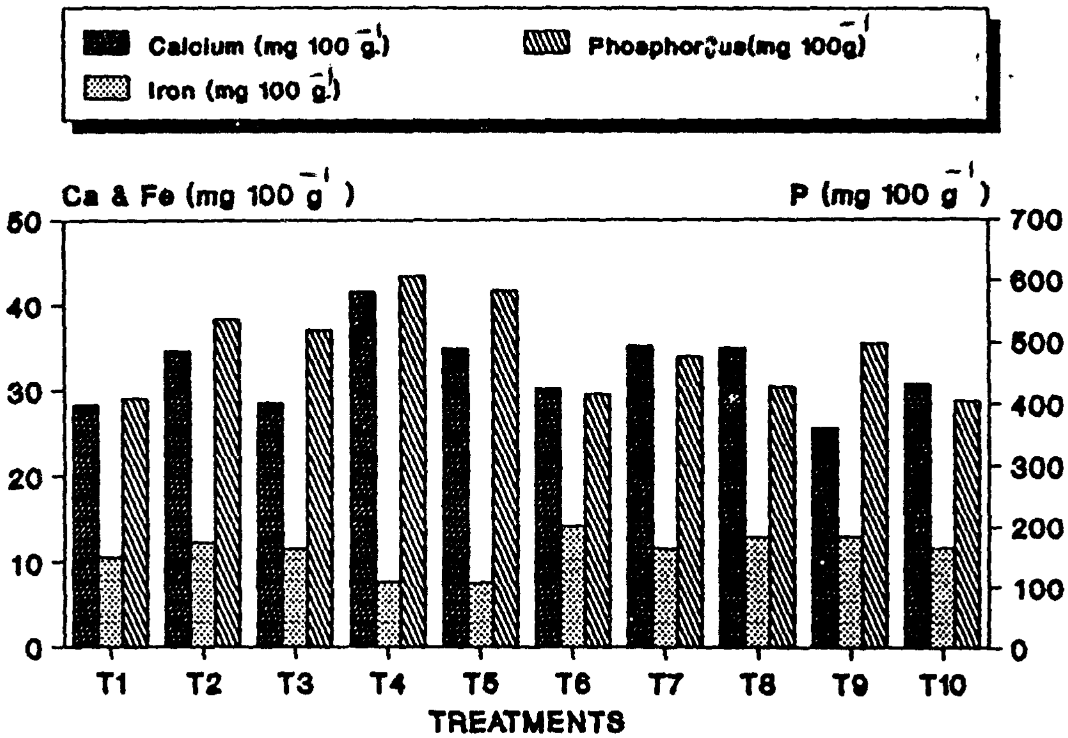

FIG. 13. EFFECT OF DIFFERENT SUBSTRATES ON Ca, P, Fe, CONTENTS OF MUSHROOM.

Data presented in Table. 16 revealed that the Ca content of fresh *Pleurotus* fruit bodies differed significantly and found in the range of 25.8 mg $100g^{-1}$ to 41.54 mg $100g^{-1}$. However, significantly highest Ca content *Pleurotus* was found in respect of treatment T4 (41.54 mg $100g^{-1}$). The Ca content of *Pleurotus* in respect of T7 (35.24 mg $100g^{-1}$), T8 (35.01 mg $100g^{-1}$), T5 (34.97 mg $100g^{-1}$) and T2 (34.50 mg $100g^{-1}$) treatments were found statistically on par with each other. The lowest value of calcium content was found in respect of T9 treatment (25.80 mg $100g^{-1}$). Similar results were also obtained by Bano *et al.*, (1981), Mueller *et al.*, (1985), Bisaria *et al.*, (1987).

4.6.2 Phosphorous

Data presented in Table 16 and Fig.13. showed that P content of fruit bodies of *Pleurotus* significantly influenced by different substrates. The range of P content of mushroom fruit bodies under different substrates was 404.43 to 607.83 mg $100g^{-1}$ however the highest P content was found in respect of T4 treatment (607.83 mg $100g^{-1}$) followed by T5 (582.98 mg $100g^{-1}$) they were statistically at par with each other. The P content of fruit bodies of *Pleurotus* under T8, T6, T1 and T10 treatments were also found at par with each other. The P content in mushrooms which are essential mineral for human nutrition, was higher than those of many fruits and vegetables (Arkroyed, 1966). These observations are found in accordance with those of Bisaria *et al.*, (1987). They reported the P content of fruit bodies range from 484 to 680 mg $100g^{-1}$.

4.6.3 Iron

Iron is an important constituent of blood. A greater part of iron in the body is present as hemoglobin. In India iron disorders are more common, while mushroom is a fair source of Iron. Data on the iron content of *Pleurotus* fruit bodies grown under different substrates' are presented in Table. 16 and Fig. 13.

The Iron content of mushroom fruit bodies were significantly influenced by the different substrates. The highest iron content of mushroom was found in respect of T6 (14.23 mg $100g^{-1}$), T9 (13.16 mg $100g^{-1}$), T8 (13.06 mg $100g^{-1}$), and T2 (12.33 mg $100g^{-1}$), treatments were found at par with each other. The lowest iron content of mushroom was found in respect of T4 and T5 *treatments* which were statistically on par with each other. Similar values of iron content of mushroom was also reported by Mostafa *et al.,* (1991).

Anderson & Fellers (1942) reported that iron content of mushrooms slightly less than the total iron which is readily utilized by the human body. These results were also similar to those reported by Bisaria *et al.,* (1987), Mueller *et al.,* (1985).

4.7 Impact of different substrates on quality of mushroom

In general it could be summerized that the crude protein content of the substrates could not exert substantial influence on the crude protein content of mushroom. Regarding calcium and phosphorous content of mushroom it was observed that there is no direct corelation between their concentration in the substrates and mushrooms, this indicated that these nutrients are not limiting factor for quality and yield of mushroom. Therefore it appears that there meight be some other factors or constituents of the substrates which influence the quality of mushroom which needs further investigations.

Chapter Opener Page

SUMMARY AND CONCLUSIONS

5. SUMMARY AND CONCLUSIONS

Investigations were carried out to " Study the effects of different substrates on yield and quality of mushroom (Sp. Pleurotus sajor-caju)". A laboratory experiment was conducted in a completely randomized block design with three replications during 1994 at AICMIP, College of Agriculture, Pune-5. There were ten treatments of different substrates used in alone and in combination as a media for mushroom cultivation.

Beside the yield data, morphological characters and quality aspects were also recorded. The substrates before and after mushroom cultivation were analysed for chemical composition and the fresh mushrooms were analysed for proximate composition. The results of the experiments led to the following conclusions.

1. It was observed that the nitrogen content of substrates increased significantly due to cultivation of mushrooms. Among substrates under study highest N increase was observed in cotton stalks (0.80 to 2.34 %).
2. Among the different substrates used for the mushroom cultivation, the cotton stalks and leaves have the highest crude protein content.
3. The mineral matter content of different substrates were decreased due to cultivation of mushroom. The highest decrease in mineral matter was observed in *bajra* stalks and leaves (15.45 to 11.61 %).
4. Organic carbon content and C : N ratio of spent straws was also decreased due to mushroom cultivation. Highest

degradation of organic carbon content was noticed in groundnut creepers (44.61 to 37.74%). It was further observed that the C : N ratio of wheat straw drastically reduced (88.15 to 19.31).

5. Increase in the calcium content of different straws was noticed when used for cultivation of mushroom. The highest content of calcium was observed in paddy straw (328.51 to 382.50 mg $100g^{-1}$.) and this was followed by *bajra* stalks and leaves (215.83 to 278.73 mg $100g^{-1}$).

6. The phosphorous content of substrates was also found increased due to cultivation of mushroom. Highest increase found in wheat straw (76.44 to 120.90 mg $100g^{-1}$).

7. Different substrates influenced the crude protein and dry matter content of *P. sajor-caju*.

8. The carbohydrate content of mushroom fruit bodies was influenced by different substrates.

9. Regarding morphological observations viz. number of sporophore, weight of sporophore, stipe length and pileus size were found tobe influenced by different substrates.

10. Fat content of mushroom fruit bodies were significantly influenced due to use of different substrates as media for mushroom cultivation.

11. Crude fibre and mineral matter contents of mushroom fruit bodies were influenced due to different substrates. Highest crude fibre content was observed in mushroom fruit bodies grown on cotton stalks (1.13 %) and highest mineral matter was seen in mushrooms grown on groundnut creepers (1.06%).

T-3266

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12. There was increase in calcium content of mushroom fruit bodies under different substrates. The highest calcium was observed in fruit bodies grown on maize stalks and leaves (41.54 mg $100g^{-1}$).

13. Differences in phosphorous content of fruit bodies of mushroom cultivated on different substrates were noticed. Among all of the substrates used maize stalks and leaves showed highest phosphorous. (607.83 mg $100g^{-1}$).

14. Iron content of mushroom fruit bodies was observed highest in cotton stalks and leaves (14.23 mg $100g^{-1}$) among all of the substrates under study.

15. The yield and biological efficiency of mushroom fruit bodies influenced by the use of different substrates for cultivation. The higher yield was noticed in cotton stalks (914.03 g) with biological efficiency 91.40% as compared with rest of the substrates.

CONCLUSIONS

Results indicated that the cotton stalks would be the highly suitable media for obtaining higher yield of mushroom, with better quality. The studies also revealed that the substrates such as paddy straw, wheat straw, soybean straw and

soybean straw + wheat straw (1:1) and *bajra* stalks and leaves could also be used as the suitable substrates for obtaining optimum yield of mushroom (*P. sajor-caju*). It could be concluded from the present investigation that the quality of mushroom in respect of crude protein, mineral matter, carbohydrates and fat content is largely governed by the kind of substrates used for its cultivation.

The nutritive value of substrates was also increased significantly after their use for mushroom cultivation. Hence spent substrates can be used as nutritious cattle feed. The straw after mushroom cultivation may also be used as a organic manure for boosting the crop yield.

Chapter Opener Page

LITERATURE CITED

6. LITERATURE CITED

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VITA

7. VITA

ANAND. B. JADHAV

A candidate for the degree

of

MASTER OF SCIENCE
in
AGRICULTURE

(1995)

Title of Thesis	:	STUDEES ON THE EFFECTS OF DIFFER ENT SUBSTRATES ON YEILD AND QUALITY OF MUSHROOM. (SP. *Pleurotus sajor-caju*)
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