DEDICATION

"Educate, agitate & organize"
the great message he had given to us
&
converted us from slave to free citizen of India.

Dedicated to
great mission of
Dr. Babasaheb Ambedkar

... ***Balu*** ...

RESIDUAL EFFECT OF SPENT WASH SOLIDS, SPENT WASH-PRESS MUD COMPOST ON WHEAT AND ON SOIL PROPERTIES (SIXTH YEAR)

By

Balu Waman Dethe

(Reg. No. 95044)

A Thesis Submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722 DIST.-AHMEDNAGAR
Maharashtra State (India)

In partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL CHEMISTRY

DEPARTMENT OF AGRICULTURAL CHEMISTRY AND SOIL SCIENCE
POST GRADUATE INSTITUTE,
MAHATMA PHULE KRISHI VIDYAPEETH,
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1997.

****

CANDIDATE'S DECLARATION

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

Place : MPKV, *Rahuri*.

Dated : 16 / 7 / 1997.

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CERTIFICATE

This is to certify that the thesis entitled, "**RESIDUAL EFFECT OF SPENT WASH (DISTILLERY EFFLUENT) SOLIDS, SPENT WASH-PRESS MUD COMPOST ON WHEAT AND ON SOIL PROPERTIES, SIXTH YEAR**, submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, (Maharashtra), in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL CHEMISTRY**, embodies the results of a piece of *bona fide* research work carried out by **MR. DETHE BALU WAMAN**, under my guidance and supervision and no part of the thesis has been submitted for any other degree or diploma in other form.

The assistance and help received during course of this investigation and source of literature referred to have been duly acknowledged.

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Dated : 17 / 7 / 1997.

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Place : MPKV, Rahuri.
Dated : 24/7/1997.

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(V.M. PAWAR)

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Place : MPKV, Rahuri.

Date : 16 / 7 /1997.

(B.W. DETHE)

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Introduction

1. INTRODUCTION

Agriculture is developing rapidly and there is rapid increase in number of sugar factories and alcohol distilleries. This rapid development of agriculture and agro-based industries created number of problems particularly the disposal of huge stock of refuges or wastes and effluents. Molasses, the by-product of sugar factory is used for alcohol production in alcohol distilleries.

In India, there are over 284 distilleries with potential of producing nearly 2730 million liters (installed capacity) of alcohol per year (Anonymous,1995). In distillery, spent wash is obtained as waste product after distillation of fermented mash (molasses + yeast) for alcohol production. The quantity of distillery waste commonly known as spent wash produced in a distillery is about 12-15 times that of alcohol produced (Manohar Rao, 1983).. At this rate, the production of spent wash could be estimated as 40950 million litres from 2730 million litres of alcohol that could be produced per annum (Anonymous, 1995) in the country. For Maharashtra, it could be estimated as 7825 million liters from 65 distilleries that can produce 655 million liters of alcohol per annum. The demand for alcohol as a source of energy, raw material for chemical industry and potableness will always increase and so the spent wash generated.

Spent wash is highly coloured by-product of distillery industry with low pH, high BOD, COD, total solids and volatile solids. Fresh spent wash is harmful and corrosive. It is highly acidic and toxic and normal microflora and fauna can not survive in it except few fungi which can grow slowly. Spent wash can affect dissolved oxygen concentration in streams and other temperature dependent physical, chemical and biological reactions adversely when discharged in natural water streams. Since it has high BOD, it putrifies rapidly giving rise to offensive odours. The reddish brown colour of the spent wash is aesthetically objectionable and it may find its way to pollute well water, imparting its colour and odour to drinking as well as irrigation waters. Satyanarayan *et al.* (1980) found that in monsoon zone distilleries, well water was coloured (brown) due to seepage of spent wash. Prolonged land irrigation using spent wash, if not sufficiently diluted, is feared to cause soil sickness. It poses a threat to aquatic life. It even corrodes pumping sets.

The spent wash is thus, a potential source of water pollution, bears immense ecological significance as rise in its volume will continue with growth of sugar industry. Any attempt to explore the possibility of utilizing the spent wash for beneficial purposes has economic, social and environmental significance and has immense practical utility.

In view of the huge stock of spent wash and above pecularities of spent wash, the problem of its disposal without causing environmental pollution has attained a great importance today and has compelled us to think and find out suitable ways and means to tackle it.

At present, various methods are adopted by distilleries for disposal of spent wash. The most common method is lagooning of spent wash. In Maharashtra, farmers have started applying sun-dried spent wash solids from lagoons to soil for crop production. However, the spent wash solids can be more dangerous than the liquid spent wash. The solids are in concentrated form may gradually and continuously release the salts of Ca, Mg, Na and other related organic compounds which might hasten the secondary salinity. Second method is to concentrate the spent wash and to burn it. In this process, ash is obtained as a residue which need to be disposed off in a suitable way. Third method is the production of methane which also gives out huge amount of spent slurry (though of a lesser BOD) which also poses a problem of disposal. Wheatever the method adopted for disposal of spent wash, the secondary products obtained have to be disposed off and ultimately it comes to land disposal.

Recently, Subba Rao (1988) proposed the composting of spent wash with press mud which is a by-product of sugar industry readily available at factory sites and may prove as a viable techonology for distillery waste disposal. Some of the distilleries in Maharashtra, have adopted this method.

Being a cheaper method, it is likely to be adopted by other distilleries also. There can be widespread use of this compost on agricultural land and it is likely that all the spent wash produced may finally find its way to the agricultural land. In Maharashtra, some of the farmers around distilleries use the spent wash-press mud compost and spent wash soilds (left in lagoons after sun drying) for crop production particularly for sugarcane, because of their manurial value, without knowing their effects on soils properties, crop growth, etc.

The soils on which sugarcane is grown in Maharashtra are Vertic Ustropepts and Typic Chromusterts. The shrinkage and swelling characteristic of these soils change the porosity and the movement of air in soils. Continuous use of spent wash containing products may affect the aeration by sealing the macro and micro-pores and may have adverse effects on the hydraulic properties of soils (Jadhav and Savant, 1975) and on growth of plants.

In view of the peculiarities of spent wash mentioned above the adverse effect of its direct use on soil properties and crops have been reported by many workers and increase in the use of spent wash in the form of compost, it is very imperative to assess the effect of spent wash solids and spent wash-press mud compost in crop sequence and on soil properties, particularly the residual effect of their long term use on crops and soil properties.

A long term field experiment was therefore, conducted from the year 1990-91 with following objectives :

1. To study the effect of spent wash soilds (SWS) and spent wash-press mud compost (SWC) and their interval of application on the yield and nutrient uptake by *kharif* (June to October) sorghum grown for fodder.

2. To study the residual effect of SWS and SWC and their interval of application on the yield and nutrient uptake by (November to March) wheat taken after *kharif* sorghum as a sequence crop.

3. To study the effect of application of SWS and SWC and their interval of application on some physical and chemical properties of soil after harvest of sorghum and wheat crops.

However, the objectives of the present study (sixth year of long term experiment conducted during 1995-96) reported in this thesis are :

1) To study the residual effect of SWS and SWC and their interval of application on yield and nutrient uptake by wheat.

2) To evaluate the residual effect of SWS and SWC and their interval of application on important physical and chemical properties of soil after harvest of wheat.

Review of Literature

2. REVIEW OF LITERATURE

In countries like India and Brazil, molasses is used as a raw material for manufacture of ethyl alcohol by fermentation process. For production of ethyl alcohol from molasses, it is diluted using large quantities of water before subjecting it to fermentation with the usual yeast (*Saccharomyces cerevisiae*). The fermented mash containing alcohol is subsequently distilled. The fermented mash is deprived of its alcohol content and the liquid left after distillation is generally known as distillery effleunt. However, in some countries it is also known as stillage (Vinhoto), vinasse, slops, still residue, spent wash, etc. (Manohar Rao, 1983).

Many workers have used spent wash and press-mud in crop porduction. Work done on use of spent wash and press-mud in crop production and different aspects of use of compost prepared from spent wash and press mud is reviewed and pertinent literature is presented in this chapter in following sub-headings :

2.1 Composition of spent wash
2.2 Effect of spent wash on soil properties, yield and nutrient uptake by crops
2.3 Press-mud production and composition
2.4 Effect of press on soil properties, yield and nutrient uptake by crops
2.5 Composting of spent wash with press mud and its composition
2.6 Effect of compost prepared from spent wash and press-mud on yield, nutrient uptake by crops and on soil properties
2.7 Effect of nutrients and FYM combination on nutritive value of crops

2.1 Composition of spent wash

The characteristics of spent wash as reported by different workers are presented in Table 1.

Savant *et al.* (1980) investigated the chemical nature of spent wash solids (spent wash dried in an oven) (SWS) and FYM and reported that the SWS contained more ether, alcohol and hot water soluble fractions than FYM. The hemicellulose, cellulose and lignin + protein fractions were comparatively more in FYM than in SWS. The SWS contained more inorganic N and less unhydrolysable N than FYM, while it was poor source of total as well as inorganic P compared with FYM. The total K content of SWS was about 12 times more than FYM. The SWS contained 2.36 per cent humic acid (HA) and was four times less than FYM, whereas fulvic acid (FA) contents were practically poor. The HA/FA ratio of SWS was very narrow as compared with FYM. The HA from SWS was more hydrophillic in nature and has less degree of aromatization as compared with HA extracted from SWS which was slightly more than that of HA extracted from FYM. The total acidity of HA and FA and humin extracted from SWS and FYM was of the following order: FA > HA > Humin.

Kulkarni *et al.* (1987) stated that spent wash was a major pollutant because of its high organic contents. The high BOD caused depletion of dissolved oxygen and proved very harmful to aquatic life. They classified spent wash as dilute

Table 1. Characteristics of spent wash

Sr. No.	Characters	Manohar Rao (1983)	Kulkarni et al. (1987)	Patil et al (1987)	Patil (1994)
1.	Colour	Raddish brown	Dark brown	Raddish brown to dark brown	Dark brown
2.	Odour	Caramel smell	Sweet	Unpleasant smell of burunt sugar	Unpleasant
3.	Temprature 0°C	80	---	90 - 95	95
4.	Specific gravity Mg m^{-3}	---	---	1.04	1.04
5.	Brix (°)	11.5 - 12.5	---	---	8.20
6.	pH	4.0 - 4.8	3.5 - 4.0	---	4.02
	mg L^{-1}				
7.	BOD	30,000 - 45,000	40,000 - 50,000	45,000 - 55,000	50,250
8.	COD	88,000 - 1,24,000	90,000 -100,000	90,000 -110,000	79,212
9.	Total solids	103,000 - 110,000	80,000 - 90,000	80,000 - 90,000	75,000
10.	Volatiles	65,000	50,000 - 60,000	55,000 - 67,000	54,900
11.	Suspended solids	---	300 - 400	300 - 500	---
12.	Total nitrogen	1200 - 1500	1000 - 1200	1200 - 1400	1510
13.	Free ammonia as N	70	30 - 40	---	---
14.	Phosphorus	250 - 370 as P_2O_5	---	800 - 1200	875
15.	Potassium	8000 - 10,000	8000 - 12,000	8000 - 13,000	9300
16.	Sodium	---	1000 - 1200	1100 - 1400	1210
17.	Calcium	---	2000 - 3000	2100 - 3300	1710
18.	Magnesium	---	2000 - 3000	2000 - 3300	1106
19.	Iron	---	50 - 70	50 - 75	348
20.	Chlorides	---	5000 - 6000	5000 - 6000	5610
21.	Sulphates	---	4000 - 8000	4000 - 8000	7300
22.	Ash	34,000 - 40,000	---	---	23,000

liquid organic fertilizer with a high potassium content and further stated that it contained about 90-93 per cent water and 7-10 per cent solids. Its nitrogen was mostly in colloidal form behaving as a slow release fertilizer and was found better than most inorganic N sources. The two third of phosphorus was also in organic form. The metabolic availability of which was more than any inorganic source. Moreover, it contained large amount of such improtant secondary elements as Ca, and Mg as well as micronutrients such as Cu, Mn and Zn. It contained 29.06 per cent mineral matter, 11 per cent reducing sugars, 9.0 per cent proteins, 1.5 per cent volatile solids, 21.0 per cent gums, 4.5 per cent combined lactic acid, 1.5 per cent combined organic acids, 5.5 per cent glycerol and 15 per cent wax and phenolic substances.

Patil *et al.* (1987) stated that spent wash was highly acidic and carried a huge organic load and total solids. It contained a good amount of potassium and high concentration of chlorides and sulphates. Besides, spent wash was highly viscous and corrosive type of liquid.

Johri (1987) reported that most of the old distilleries were using batch fermentation process producing dilute vinasse. The modern continuous fermentation process with yeast recycling, produced concentrated vinasse and at the same time has higher alcohol yields. Typical data for the two processes reported by him for a distillery of 45000 liters per day alcohol capacity are given below :

Characters	Batch process	Continuous process
Vinasse quantity ($m^3 day^{-1}$)	600 - 700	235
Specific gravity ($Mg\ m^{-3}$)	1.03 - 1.05	1.101
Temperature (oC)	105	110
BOD ($mg\ L^{-1}$)	43000	68000
COD ($mg\ L^{-1}$)	78000-90000	177000
Total dry solids(%)	7.8 - 9.0	23 - 24
Ash (%)	2.20	5.40
K_2O (%)	0.85	1.90
Na_2O (%)	0.24	0.73
CaO (%)	0.21	0.91
Sulphates	0.48	1.50
ICV of dry solids ($kcal\ kg^{-1}$)	3100	3300

Corri *et al.* (1988) reported that vinasse has the highest content of organic N, nutrients and ash and bagasse contained the least. Organic compounds extracted by alkaline reagents were of humic nature and were similar to those found in the soil except that fulvic acid predominated over humic acid.

Kulkarni *et al.* (1990) reported the presence of sugars (2 to 20%) and proteins (10 to 11%) in the dry spent wash along with mineral component.

Patil (1994) found Fe-348, Mn 12.7, Zn - 4.61, Cu-3.65, Cr - 0.64, Cd- 0.48, Co-0.08 mg L^{-1} and NO_3 traces in spent wash with a EC value of 16.5 dS m^{-1}.

Palve (1995) found Fe-1270, Mn 397, Zn-123, Cu-86 Mo traces, Cr-185, Ni-127, Cd-47, Co-19 mg kg^{-1} in spent wash ash.

2.2 Effect of spent wash on soil properties, yield and nutrient uptake by crops

Because of presence of mineral nutrients in spent wash it has been used in crop production by many workers.

Escolar (1963) observed changes in hydraulic conductivity, aggregate stability and improvement in infiltration rate by addition of distillery slops and molasses to the column of saline sodic soil (Escolar, 1966). Escolar (1966) observed increase in yield, P, K and Cu uptake by snap bean due to spent wash application.

Doragi *et al.* (1968) stated that distillery waste applied in combination with heavy rates of fertilizer depressed the growth of lucern.

Guimares *et al.* (1968) found that 382 kg ha^{-1} as economic dose of vinasse and vinasse + NPK for sugarcane. Yang (1968) observed that 80 t ha^{-1} spent wash alone (1:3 dilution) and in conjunction with NPK incresed sugar yield by 10 to 12 and 1 to 3 per cent, respectively in cane crop, while values were 16 to 17 and 3 to 8 per cent for ratoon crop of sugarcane. Bajpai and Dua (1972) and Agarwal and Dua (1976) obtained significant higher yield of sugarcane and available N content of soil with 200 kg N through spent wash ha^{-1}.

Incubation studies conducted by Jadhav and Savant (1975) indicated that application of spent wash increased pH, EC, cations, anions, SAR, PAR, exchangeable Na and K and decreased exchangeable Ca and Mg content of soil. Singificant rise in COD of saturation paste extract of soil was observed. Beneficial effect on available N, P and K content of soil was observed. However, they noted adverse effect on water retention, hydraulic conductivity and water stable aggregates of soil.

Jagdale (1976) indicated that non-judicious use of spent wash may adversely affect the growth of sugarcane plant and properties of sugarcane soil. Growth and chemical composition of sugarcane and juice were not adversely affected by 250 mg kg^{-1} spent wash solids but higher rates had adverse effect (Jagdale and Savant, 1979). Cooper and Prasad (1976) observed significant increase in sugarcane yield with 50 tonnes distillery waste per acre. They indicated that distillery waste was supplying considerable amount of available K. While 42 m^3 ha^{-1} dose of spent wash was found optimum by Stupiello *et al.* (1977) for increasing yield of sugarcane. Rodella and Ferrari (1977) observed increase in ash and K content of raw and clear cane juice and molasses by application of vinasse.

Arbatti (1976) obtained five times increase in yield of pearl millet by application of spent wash solids (evaporated in tenches). Similarly, Dongale and Savant (1978) stated that the spent wash was as good as KCl as a source of potassium for sorghum (M 35-1). Application of vinasse with barley stubbles at 1.6 and 3.2 t ha^{-1} increased yield of phaselia which was 1.7 and 13.2 t ha^{-1} dry matter, respectively. Vinasse applied with fertilizer increased potato and sugarbeet yields by 10 and 20 per cent, respectively (Debruck and Lewicki, 1980).

Singh *et al.* (1980) found that addition of spent wash without dilution was very effective in increasing water intake rate of sodic calcareous soil and pH. The salt content of soil decresed to rate limit. The exchangeable Na percentage was reduced from 100 in the original soil to two in top 15 cm. They indicated that the spent wash application followed by irrigation rather than dilution of spent wash at the time of its application was very effective in reclamation of sodic soils.

Nunes *et al.* (1981) applied increasing levels of spent wash and observed that total N and C levels and exchangeable Na content of soil were not affected. However, exchangeable K,Ca,Mg, pH, available P and nitrates decreased.

Sontos *et al.* (1981) observed that germination of maize decreased by 50 per cent after application of 800 m^3 ha^{-1} and by 65 per cent with 1600 m^3 ha^{-1} wine waste. Increase in application rate increased soil pH, shoot and root dry matter upto 800 m^3 ha^{-1}. At 1600 m^3 ha^{-1}, sharp decrease in root and shoot dry weight, K content and increase in tissue succulence were noted by them.

Silva *et al.* (1981) reported that application of 30 m^3 ha^{-1} vinasse alone considerably improved yield of cane and sugar ha^{-1}. Significant increase in cane yield and recoverable sugar ha^{-1} due to application of spent wash at the rate of 90-150 t ha^{-1} was observed by Vieiria (1982). Monteiro *et al.* (1982) concluded that vinasse influenced stalk production of sugarcane and indicated that supplemental N provided further gain. The technological quality of cane for sugar manufacture was not affected by vinasse application with or without N and P.

Gonzales and Tinaco (1982) indicated that distillery slops application at the rate of 83, 166 and 249 m^3 ha^{-1} with regular fertilizers significantly increased cane and sugar yields, soil pH, available K_2O, Ca and Mg content of soil and ash per cent in juice was increased by slops application.

Cooper and Abuidris (1982) obtained significant increase in cane and sugar yields, K in leaf and available K content of soil by vinasse application to first ratoon.

Godbole (1984) suggested that spent wash from lagoon had to be diluted with fresh water preferably to 100-fold to bring down the BOD to 500 mg L^{-1} for its disposal on land. This had no effect either on pH or on water holding capacity of the soil, However, it had also been reported by him that acidity of the effluents apart from damaging the crops might do irreparable harm to the soil through leaching and the neutralization of the spent wash with lime would affect the ion balance of the soil and thus would have long term deleterious effects.

Camargo *et al.* (1984) found that vinasse, KCl and K_2SO_4 increased pH of soil and enhanced nitrification. Orlandt *et al.* (1985) applied vinasse up to 20 years and found that the soil was benefitted in terms of pH, higher K, Ca and Mg contents and showed greater CEC.

Robina *et al.* (1986) found that vinasse increased yield of sugarcane where soil contained less than 35 per cent clay. Only 20 per cent of the trials conducted by them showed the increase in yield of sugarcane where the clay content was greater than 35 per cent. They concluded that the vinasse effect was influenced by soil texture and fertility. Use of mineral supplementation was more effective when the clay content of the soil was below 35 per cent and the pol content of cane was not affected.

Marod *et al.* (1986) observed that levels of vinasse increased cane and sugar yields but reduced pol content apparent purity, brix and sugar yield. Vinasse raised the soil pH and the effect increased with increasing amounts of vinasse. The stand of leguminous inter crop with cane were reduced by vinasse applied at a very early stage of plant growth.

Scandaliaris *et al.* (1987) reported that application of spent wash to soil increased the soil nitrate availability, EC, interchangeable K and yield of sugarcane. Best results obtained with 150 and 300 m^3 ha^{-1}. However, the treatment reduced the cane quality with drop in pol content, purity and increase in ash content.

Pande and Sinha (1988) obtained marked increase in dry matter production of cane stalk, fresh weight, height of stalk with 70 m^3 vinasse ha^{-1}. However, enhanced sucrose content was observed at 35 m^3 vinasse ha^{-1}.

Vieites and Brinholi (1991) found that application of vinasse at 45, 90 and 180, 270 m^3 ha^1 lowered the juice pol and expected yields of sugarcane and alcohol significantly. The higher doses resulting in higher decrease in expected yields.

Ghugare *et al.* (1988) reported that spent wash application (50-75 times diluted) recorded significantly higher available P and K contents of soil.

Tauk and Madeiros (1989) also observed increase in soil pH available N, P, K, Ca and Mg with 80 m^{-3} vinasse ha^{-1} application.

Pawar *et al.* (1992) found that addition of diluted spent wash decreased pH and electrical conductance. There were significant changes in soil. The nutrient supplying status of the experimental soil improved considerably as evidenced by the performance of sugarcane grown on the soil under pot culture condition. In a pot study, Patil and Shinde (1995c) observed decrease in yield and nutrient uptake by single application of undiluted spent wash at sowing of maize. They observed the following decreasing trend of CO_2 evolution in soil incubated with different sources : spent wash > press mud > spent wash - press mud composts > lagoon dried spent wash solids > FYM and attributed decrease in yield to higher CO_2 evolution resulting in reduced root growth and nutrient uptake.

Singh *et al.* (1995) studied the effect of spent wash (two applications) on soil properties, sugarcane yield and juice quality and found that spent wash addition in soil increased the population and activity of micro-organisums. Cane yield was increased by 26 per cent due to addition of 120 m^3 spent wash ha^{-1} (two split) to soil. The fertility status with respect to available N and K was higher in soil treated with spent wash. Soil hydraulic conductivity however, increased by 17 per cent over control. There was no adverse effect on juice quality.

Zalawadia *et al.* (1996) studies the effect of distillery waste water with fertilizer on onion and soil properties. Both fresh and dry yields of onion bulbs increased significantly by different treatments. With respect to soil properties excepting pH all other properties were significantly affected due to different treatments. Considerable increase in EC value was noticed in the distillery water treated pots in comparison with tube well water treated pot. Similarly, increase in organic carbon and available K contents in the soil were also observed.

2.3 Press mud production and composition

In sugar factory, after milling of cane the raw juice is processed by adding specific quantity of triple superphosphate solution, then heated and further processed either by carbonation or sulphitation processes. The impurities are settled in the form of mud in `Dorr'. The mud is taken out in mud mixer where bagasse powder is mixed and the material is collected in mud tank which is delivered to 'Oliver' (filter press) where the cake is build up and after washing the cake are partially dried and discharged through oliver which is commonly known as press mud or press mud cake. It is also called filter mud, filter cake or cachaza (Haines, 1961).

In India, on the basis of 3 per cent, i.e. 3 metric tons of press mud per 100 metric tons of cane milled (Kale and Shinde, 1986), the potential of press mud production could be estimated as 4020 thousand metric tons from the

13398 thousand metric tons of cane crushed during the year 1992-93 (Anonymous, 1994).

Eastwood (1974) determined the percentage of C, N, P_2O_5 and K_2O, Ca and Mg in the dry filter cake and stated that press mud was equivalent to 1.21 to 2.00, 0.84 to 2.07 and 0.07 to 0.1 of sulphate of ammonia, triple superphosphate and muriate of potash, respectively.

Halm and Dennis (1976) reported that the press mud cake had high concentration of total N, organic matter and available K with the mean values of 0.71, 4.1 per cent and 1500 mg kg^{-1}, respectively. The contents of available P, total P and exchangeable Ca were 400, 1300 and 600 mg kg^{-1}, respectively.

Jafri *et al.* (1985) found that processed press mud cake contained appreciable quantity of various micronutrients such as Fe 0.189, Mn 0.045, Cu 0.012 and Zn 0.017 per cent on oven dry basis. Its pH was slightly alkaline (7.9). However, It had high content of organic carbon (11.2%). The quantity of macronutrients such as N, P_2O_5, K_2O, S and CaO were 4.9, 6.23, 3.78, 1.05 and 0.41 per cent, respectively.

Patil *et al.* (1983) collected the samples of press mud cake from varios sugar factories in Maharashtra at monthly intervals and reported that the press mud cake contained 33.98 per cent organic carbon. It was a good source of N (1.63%), P_2O_5 (2.52%) and K_2O (0.55%). The P_2O_5 was the major nutrient present. The pH of air dried press mud cake was 6.4. The samples contained high concentration of total soluble salts and 4.74 per cent free lime. They further opined that it could be a good source of Ca.

Kale and Shinde (1986) stated that press mud cake was soft, spongy, amorphous dark brown material containing about one per cent crude fibre, coagulated proteins, cane wax, albuminoids, inorganic salts and soil particles.

Torries *et al.* (1988) in Cuba, evaluated the physical, chemical properties of 14 samples of filter mud from Antonia Guiteras cane factory. They observed that the content of crude wax was 11.33 $\pm$ 2.28 per cent and ash content was 17.6 per cent which would hinder the wax extractions. It was opined by them that the press mud could be used as a source of wax.

In Pakistan, Jamil *et al.* (1990) analysed the samples of filter press mud from five cane sugar factories. They reported the useful constituents which were, wax 1 to 3 per cent and crude protein 9 to 11 per cent.

Sood (1992) stated that the sulphitation process filter cake has great manurial value. He found that the carbonation process press mud cake, being rich in calcium oxide and was not usable as a manure, However, in some cases, where the soils are acidic, this press mud cake was used after mixing with compost.

Patil and Shinde (1995a) observed N 1.9, P 1.8, K 0.9, Ca 4.3, Mg 0.7, S 5.2 and Na 0.1 per cent and Fe 3544, Mn 541, Zn 89 and Cu 53, mg kg^{-1} in the press mud of Rahuri Sugar Factory. The humic acid and fulvic acid content was 14.2 and 24.9 per cent, respectively. They observed lower hydrolysable N in the press mud than FYM and its contribution to the total N in the press mud was also lower than FYM. The proximate composition was ether soluble (Fat, oil and waxes) 7.65, alcohol soluble (resins) 3.86, hot water soluble (polysaccharides) 15.75, 2 % HCl soluble (hemicellulose) 1.58, 80 % H_2SO_4 soluble (cellulose) 8.24 and lignin + protein 3.51 per cent in the press mud.

2.4 Effect of press mud on soil properties yield and nutrient uptake by crops

Increase in hydraulic conductivity and soil moisture content was noted with application of press mud at the rate of 15.1 and 30.2 t ha^{-1} by Paul (1974).

Patil *et al.* (1978) observed that application of 12.5 t ha^{-1} of press mud had comparable effect as that of N, P and K artificials on yield parameters. Improvement in juice quality was also noticed due to incorporation of press mud cake over the use of N, P and K artificials.

Indira Raja and Raj (1979) observed improved stability of aggregates in black and acid soils and increased organic carbon and available N content of these soils by application of 10 t ha^{-1} press mud. However, germination of *ragi* seeds was affected by 10 t ha^{-1} press mud. Better growth of seedlings and uptake of N, P and K was observed by 5 t ha^{-1} press mud (Indira Raja and Raj, 1980). Arzola Pina and Monomou (1981) observed increase in pH, organic matter and nitrogen content in brown tropical soil by application of press mud. Higher green gram yield with press mud than inorganic fertilizer and increase in available K in black clay soil was noticed by Borde (1981).

Patil and Shingate (1981) observed that sucrose content of cane juice was improved at lower doses of press mud, while higher doses of press mud increased the N/P_2O_5 ratio and mineral matter of the juice.

Datta and Gupta (1983 a) found that the 20 t ha^{-1} press mud increased maize and wheat yields. It increased soil pH, exchangeable Ca and Mg, lime potential in soil and P and Ca uptake by maize and wheat. Press mud applied at 20 t ha^{-1} increased concentration of P in soybean and pea grains and uptake of P,K and Ca in acid soil of Nagaland (Datta & Gupta, 1983b). Increase in hydraulic conductivity, infiltration rate and decrease in pH, electrical conductivity of saline-alkali soil were observed by Khandve (1983) by press mud application.

Patil and Kale (1983) reported that 25 t ha^{-1} press mud cake increased availability of nutrients to sugarcane. The increase in organic carbon, total N and available P after harvest of sugarcane was also noticed.

Datta (1984) observed that press mud increased yields of maize and wheat and it increased uptake of P and Ca by maize and wheat grains. The press mud and lime were totally ineffective for lowland and upland rice crops. The increase in pH of acid soil was also observed. Datta and Gupta (1985) stated that increasing levels of press mud decreased the Mn content and increased Ca content of root, shoot and grain of wheat and maize.

Kumaresan *et al.* (1985) suggested that application of press mud at the rate of 5 t ha^{-1} with 37.5 kg $ZnSO_4$ and 100 kg $FeSO_4$ ha^{-1} significantly increased sugarcane yield. Jafri *et al.* (1985) observed that processed press mud cake increased the yield of cane, uptake of N, P,K and S, while it decreased the uptake of micronutrients.

Duraisamy *et al.* (1986a) found that application of gypsum + press mud increased the yield of rice in alkali soil. Decrease in soil pH and ESP and increase in EC were noticed by application of lime and press mud combination (Duraisamy et at. 1986b). Increased dry matter yield of corn was obtained with press mud and zinc combined. The concentration and uptake of N and Zn was higher in press mud and Zn combined (Gupta *et al.* 1986).

Kale and Shinde (1986) found that dewaxing of press mud increased th efficiency of press mud for crop production of rice-wheat-mung sequence. In another experiment with graded levels of press mud to groundnut-wheat sequence, they found that the application of press mud at the rate of 5 t ha^{-1} was equivalent to the recommended dose of N and P for groundnut and beneficial effects were seen on the succeeding crop of wheat.

Singh *et al.* (1986) reported that application of pyrites and sulphitation press mud to calcareous saline soils of North Bihar resulted in an appreciable decrease in pH and increase in EC of soil.

Pawar (1987) reported that the soil pH, EC (1:2.5) and $CaCO_3$ content decreased by application of press mud and increasing levels of pyrites. The available nutrients such as N, P, K and DTPA extractable Fe, Mn and Zn significantly increased by application of press mud and increasing levels of pyrites.

Ingole *et al.* (1989a) showed that application of press mud (PM) at the rate of 7.5 t ha^{-1} recorded equivalent sugarcane yield as that of inorganic fertilizers. Application of PM recorded more uptake of P by sugarcane than fertilizers. The press mud increased available P in soil after crop harvest. However, it did not affect organic carbon content and pH of soil (Ingole *et al.* 1989b).

Kapur and Kanwar (1989) observed no significant increase in N & P content of soil by application of 20 t ha^{-1} sulphitation and carbonation press mud during first year but did observe increase during second year.

Patra *et al.* (1989) repo[...] [...]ination of single superphosphate (SSP) and press mud (PM) in the ratio of 50:50 to potato and 75:25 to cabbage recorded comparable yields with that of 60 kg P_2O_5 ha^{-1}. Application of SSP and PM alone or in combination as a source of P increased yield of potato and cabbage over control by 44.7 to 52.1 and 23.9 to 48.3 per cent, respectively.

Narwal *et al.* (1990) reported that P content of the soil after harvest of wheat increased with increasing levels of applied P incubated with press mud, irrespective of the source of P.

Paramasivam and Gopalswamy (1990) reported that application of press mud at 10 t ha^{-1} was found beneficial for rice grown in two successive seasons at Madurai. Patel and Singh (1991) reported the largest yield of rice with press mud followed by gypsum and pyrites applications.

Orlando *et al.* (1991) stated that filter cake was an excellent material for adding organic matter, Ca and P to soil. With only 10 t filter cake ha^{-1}, addition of P fertilizer was unnecessary.

Patil (1991) observed that press mud (PM) was effective in increasing the nutrient uptake and yield of sorghum grown for fodder. He further observed that PM increased hydraulic conductivity, porosity, stability of aggregates and pH of soil. He also noted increase in available

Fe and Mn content of soil after harvest of sorghum and Fe, Mn and Cu content of soil after harvest of succeeding crop of wheat.

Singh *et al.* (1991) observed that application of press mud alone increased cane yield by 82.2 per cent over unfertilized control.

Kumar and Mishra (1991) reported that pH increased by application of the carbonation press mud cake and no change in pH occurred by application of sulphitation press mud.

Kant and Kumar (1992) reported that application of press mud and FYM slightly improved soil properties. Application of these amendments significantly increased the grain yield of rice (11.20%) compared with the control plots.

Yaduvanshi and Yadav (1991) reported that addition of 150 kg N ha^{-1} and 30 t press mud ha^{-1} separately increased the yield of millable cane by 38 per cent and 27 per cent, respectively, whereas their combined application increased it by 65 per cent over control. Addition of 75 kg N with 10 t press mud ha^{-1} yielded equal to that of 150 kg N ha^{-1} alone and gave the maximum benefit : cost ratio.

Madhukkur and Anaiyur Vyologam (1991) reported that press mud was rich in organic matter Ca and P and also contained some organic nitrogen and trace elements. It has been used as a soil conditioner, soil ameliorant and source of nutrients for crop growth. Press mud increased the availability of phosphorus in clayey and sandy soils and a tendency of increasing potassium availability in sandy soil.

Manoharan *et al.* (1992) recommended press mud application at the rate of 50 t ha^{-1} for sodic soil condition to sugarcane crop so as to derive increased yield and quality.

Kapur and Kanwar (1993) reported that the application of 10 and 20 Mg ha^{-1} of sulphitation filter cake (SFC) increased the root yield of sugarbeet by 21.9 and 43.5 per cent in comparison with 15.9 and 31.4 per cent by these level of FYM. An increase in sugar yield was 22.6 and 45.4 per cent in carbination filter cake (SFC) compared with 17.0 and 35.4 per cent in FYM. In contrast, CFC was inferior to FYM. The increase due to its application at 10 and 20 Mg ha^{-1} was only 10.9 and 25.00 per cent in root and 12.6 and 29.3 per cent in sugar yield of sugarbeet.

2.5 Composting of spent wash and press mud and its composition

Park and Castro Gomez (1982) observed that good quality compost was prepared when 300 kg of bagasse and 38 kg poultry manure was moistened with molasses fermentation effluent (vinasse), which contained 5.4 per cent soild substances with 7.7 per cent nitrogen content.

Polo *et al.* (1988) mixed sugarcane bagasse (B), vinasse (V) and filter cake (T) to prepare mixture either B/V

1:2 or B/V/T 1:1:1 for use as compost substrates. The mixtures were allowed to incubate for 3 month at 28oC with moisture content controlled at 60 per cent with and without addition of ammonium sulphate and gypsum to correct the C:N ratio and pH, respectively. Final loss in weight was 35 per cent and it occurred mainly during the first month in both the mixtures. Chemical properties of the material were similar in all cases. The C:N ratio decreased owing to the loss of C and the total exchange capacity tripled owing to the oxidation of the material. Water retention increased independently of weight loss.

Subba Rao (1988) reported that the time required for aerobic composting of spent wash-press mud compost was 25 to 30 days and further opined that composting of spent wash with press mud in 2:1 proportion may prove to be one of the viable technologies for distillery water disposal.

Patil (1991) described a procedure of composting of spent wash and press mud adopted by Malegaon Co-operative Sugar Factory, Malegoan, Tahsil Baramati, District Pune (Maharashtra State), which was as under :

The spent wash from alcohol distillery and press mud from sugar factory were mixed in 2:1 proportion in long trenches of 80 m x 5 m x 1.5 m size. For which the required amount of spent wash is pumped into trenches and to it the required amount of press mud was added. The material in the trenches was subsequently mixed on alternate days with excavator-cum-mixer for a week. The material was allowed to stand for a fortnight in the trenches and then removed and heaped nearby for use.

Following composition of spent wash-press mud compost was found during the five years of present long term experiment :

Sr. No.	Particulars	Patil (1991)	Kale (1993)	Arote (1993)	Ove (1995)	Belhekar (1995)
1.	pH (1:2.5)	6.59	7.15	8.20	8.25	8.20
2.	EC (dS m^{-1}) (1:2.5)	13.95	13.50	7.45	7.25	7.25
3.	Organic carbon (%)	28.02	31.84	22.60	21.27	31.90
4.	Nitrogen (%)	1.83	1.31	2.36	2.11	2.13
5.	Phosphorus (%)	0.86	0.79	0.89	1.45	1.11
6.	Potassium (%)	2.30	1.90	2.50	2.30	2.02
7.	Calcium (%)	8.49	5.50	9.82	9.40	4.00
8.	Magnesium (%)	1.21	1.68	0.81	1.13	0.90
9.	Sodium (%)	0.11	0.61	0.30	0.38	0.44
10.	Sulphate (%)	3.18	1.37	3.86	3.01	3.00
11.	Chloride (%)	1.02	0.25	1.03	1.17	1.17
12.	Iron (mg kg^{-1})	16450	9000	16750	23450	12175
13.	Manganese (mg kg^{-1})	695	420	460	575	400
14.	Zinc (mg kg^{-1})	71	99	94	108	202
15.	Copper (mg kg^{-1})	170	97	197	93	125
16.	C:N ratio	15.26	24.31	9.58	10.08	14.97

Patil and Shinde (1994) prepared composts from 2:1, 3:1, 4:1, 5:1 and 6:1 proportion of spent wash slurry (after methanation) in the laboratory with press mud and found that the 2:1 and 3:1 proportion composts showed higher temperature during early period of composting. The temperature rise was found after 20 days in higher proportion composts. They noted faster decomposition in lower proportion composts. The 2:1 proportion was found suitable for getting compost with desired C:N ratio within 15 days. The higher proportion composts required 30 days. They further stated that if time is not the constraint compost could be prepared even from 6:1 proportion. All the composts contained higher N, K and S than press mud and FYM. The humic acid (HA) and fulvic acid (FA) content of all composts were lower and were less humified and less condensed or aromatic than FYM and press mud. The contribution of hydrolysable N and NH_4-N to total N of composts was lower than FYM. Unhydrolysable N in composts was more than FYM. Similarly composts had higher ether (oils, fats and waxes), alcohol (resins), hot water (soluble polysaccharides) and 80% H_2SO_4 (cellulose) soluble fractions and lower 2% HCl soluble (hemicellulose) and lignin + protein fractions than FYM (Patil and Shinde, 1995a).

2.6 Effect of compost prepared from spent wash and press mud on yield, nutrient uptake by crops and soil properties

Takate (1992) conducted a pot culture experiment with spent wash - press mud compost (SWC) spent wash soilds

(SWS), press mud (PM), spent wash liquid (SWL), complehumus (CH) and FYM with and without N, P, K. He found that at 65 days (harvest) effect of FYM, SWS and SWL on dry matter yield of maize was similar, so also the effect of PM, SWC and control. When NPK was added to the organic sources, SWS and SWL were found superior in respect of dry matter yield of maize. The PM with NPK application produced less dry matter than NPK alone. The N and P uptake by maize was the highest in SWC + NPK treatment, while the K uptake was the highest in SWS + NPK treatment. The SWC, SWS and SWL with and without NPK raised the organic C and NPK content of soil after harvest of maize. Application of SWS, PM and SWC without NPK showed no residual effect on wheat yield. However, their application with NPK increased wheat yield. The highest soil aggregate stability after harvest of wheat was found in case of FYM with and without NPK which was followed by SWC treatment.

Results of field experiment conducted at Sugarcane Research Station, Padegaon (Anonymous, 1992) showed that the use of spent wash-press mud compost (SWC) to sugarcane increased pH, EC and organic carbon content of soil appreciably. The lysimeter study also showed maximum pH, EC, cations and anions in the leachates collected from the SWC treatment (Anonymous, 1992).

The long term field experiment conducted on soil of Sawargaon series by Shinde *et al.* (1993a) and their first year (1990-91) results of the present experiment revealed that spent wash solids (SWS), farm yard manure (FYM), spent wash-press mud compost (SWC) were equal in their effect and were found better for increasing sorghum fodder yield, while PM proved inferior. The N, K and Zn uptake from SWS and SWC was comparable. The P uptake from PM and SWC was similar. The SWC was found superior to other sources in respect of N, P, K, Fe and Zn uptake. Significant residual effect of SWC on the yield of wheat was observed. Other sources were as good as control. All the sources increased the uptake of N, P, K, Fe, Zn, Mn and Cu and SWS increased the uptake of K by wheat (Shinde *et al.*, 1993b). The SWS increased EC and available K in soil and EC of saturation paste extract of soil. All the sources increased chlorides in saturation paste extract of soil and SWC increased available N, P and DTPA - Fe, Mn and Zn, while PM raised organic carbon and SWS increased available K content of soil after harvest of sorghum. Improvement of stability of aggregates by all the sources and the hydraulic conductivity and porosity by PM and FYM application were noted after harvest of wheat taken after sorghum. All sources increased available N, K and DTPA - Fe, Mn and Cu, while SWC, PM and FYM increased organic carbon and available P content of soil after harvest of wheat (Shinde *et al.*, 1993c).

The result of second year (1991-92) of the present long term experiment reported by Shinde *et al.* (1995a) revealed that none of the sources showed significant effect on yield of sorghum fodder. However, higher N uptake by sorghum was observed in SWS which was found significantly superior to FYM and SWC. The SWC was as good as FYM and PM in respect of P uptake and better than SWS. The SWC resulted in build up of available N in soil after harvest of sorghum and was as good as FYM in respect of build up of available P in soil. The SWC and SWS increased pH, EC and concentration of Cl^- and SO_4^{2-}, Ca^{2+}, Na^+ and K^+ of saturation paste extract (SPE) of soil after harvest of sorghum. Every year application raised Na^+, Cl^- and SO_4^{2-} concentration in SPE compared with alternate year application. No residual effect of organic source was observed on subsequent wheat crop yield. Every year applicaiton showed residual effect on wheat yield. Build up of available P in soil was higher in SWC than SWS. Higher improvement in hydraulic conductivity was found with FYM and PM than SWS and SWC. Highest stability of soil aggregates was observed with FYM. Alternate year application resulted in better stability of aggregates than every year application. The SWC and SWS decreased bulk density and improved void ratio of the soil.

Shinde *et al.* (1995b) studied the third year effect (1992-93) every year (EY), alternate year (AY) and after two year (TY) applicaiton of SWS, SWC, PM and FYM in present long term experiment and the results revealed that all the organic sources increased yield of sorghum dry fodder and nutrient uptake. Higher N uptake by sorghum was observed in EY SWC and

EY SWS and proved superior to EY FYM and EY PM. The TY SWC and SWS application found better in respect of P uptake. The SWS increased K, Fe, Cu and Zn uptake by sorghum. The SWS ranked second which increased K, Fe, Cu, Mn uptake by sorghum. The SWS decreased pH of soil slightly and was found to increase EC and available K, Mn, Zn and Cu in soil and concentration of K^+, Na^+, HCO_3^-, SO_4^{2-} and Ca^{2+} + Mg^{2+} in saturation paste extract (SPE) of soil after harvest of sorghum. The SWC decreased soil pH slightly and found to increase available P in soil and K^+, Na^+ and SO_4^{2-} in SPE of soil. Every year application of all sources increased the organic carbon, available P in soil and increased EC, Ca^{2+}, Mg^{2+} and Cl^- in SPE. All organic sources increased the Cl^- in SPE. The FYM had significant effect on available P and Fe content of soil and Na^+ concentration in SPE. Every year application of all organic sources increased the concentration of K^+ and SO_4^{2-} of SPE. The SWS increased uptake of N, K, Mn and Zn in grain, straw and total N by wheat. All the sources showed equal effect on P uptake by grain, straw and total uptake. The SWC ranked second in uptake of N, K, Mn and Zn by grain straw and total uptake. The SWS increased organic carbon available K, Fe, Mn and Zn after harvest of wheat. Every year application of organic sources were found to increase available N, K, Fe, Mn and Cu content in soil. The SWC ranked second which increased available N, P, K and Fe. The PM and SWC found to increase the infiltration rate and the aggregate stability which were superior to FYM and SWS. Every year application of organic sources found superior to alternate year and after two year application in this respect (Shinde *et al.* 1995c).

Jadhav *et al.* (1992) Conducted an experiment at Cental Sugarcane Research Station, Padegaon on use of spent wash-press mud compost (SWC) to adsali cane during 1989 to 1992 and reported that soil fertility, micronutrient contents of soil and juice quality were maintained. Further application of 7.5 t ha^{-1} SWC (oven dry basis) with adjusted dose of N, P and K fertilizers (324:101:129) was beneficial to get higher cane yield (168.96 t ha^{-1}) and CCS (23.03 t ha^{-1}) over other treatments without affecting soil properties adversely. This dose (7.5 t ha^{-1}) was economical as compared with the application of 10 t ha^{-1} FYM and recommended dose of fertilizer NPK application (400:170:170).

A new technique has been developed at Central Sugarcane Reasearch Station, Padegaon during last few years was reported by Jadhav *et al.* (1993). This technique was a best combination of natural farming, fertilizer use, water management, use of spent wash-press mud cake compost (SWC) and FYM. The trash served the purpose of mulch due to which number of irrigation was reduced. The fertilizer were applied with crowbar method which helped in increasing the efficiency of applied fertilizers. By adopting this technique there was increase in cane yield as compared with burning of trash and decrease in cost of cultivation to the tune of 30 per cent. The soil fertility was also improved. Increase in yield of cane and EC, available N, P and K content of soil by use of 7.5 t ha^{-1} of SWC was observed by them.

Results of fourth year (1993-94) of the present long term experiment (Ove, 1995) revealed that SWS was superior to other sources for yield of sorghum fodder (green), while SWC was as good as FYM and PM. Increase in N, P, K and Zn uptake by sorghum was found in SWS and SWC. Every year application of organic sources proved better. Considerable increase in available K and Cu was found in SWS treated plots after harvest of sorghum. The SWC ranked second in respect of available K content. Both the sources increased available N content. The SWC was as good as FYM, while the SWS proved inferior to FYM in respect of availble P content of soil. Every year application of organic sources raised the fertility parameters in the soil. The SWS had pronounced effect on available K and Cu build up in soil. The SWS increased soluble salts of K, Na and Ca + Mg in saturation paste extract of soil (SPE) probably of HCO_3 and SO_4 types. The SWC ranked second. The EY SWS and SWC showed higher effect on composition of SPE. Organic source showed residual effect on grain and straw yields of wheat. The higher N and K uptake was found in SWS treatment, while SWS and SWC found inferior to PM in respect of P uptake. The EY application showed higher effect on N, P, K, Fe, Mn and Zn uptake. The EY SWS was found better than its alternate year and after two year applications. The PM and FYM decreased bulk density showing higher porosity and void ratio. However, PM, FYM, SWC had lower effect on water stable aggregates than SWS, while all the sources including SWS improved hydraulic conductivity of soil.

Results of fifth year study (Belhekar, 1995) showed that SWS and SWC were found better than FYM and PM in terms of sorghum fodder yield. The EY application was better than AY and TY applications. The SWS effect on P and K uptake was higher than FYM. The SWS increased Fe uptake over SWC and FYM. The EY application proved better for P, Fe and Mn uptake. The SWS and PM increased protein content of sorghum fodder and all sources increased carbohydrate and ash content. The SWS increased EC of saturation paste extract (SPE) of soil and its EY applicaiton showing the highest effect. The SWS and SWC increased available K of soil and increased K^{+}, Ca^{2+} Mg^{2+}, CO_3 and $SO^{-2}{}_4$ in SPE of soil. The FYM and PM increased the hydraullic conductivity of soil compared with SWC and SWS.

Results of fifth year study (Gawande, 1995) showed that SWS and SWC and PM showed residual effect on wheat grain yield. These source were comparable. There was no significant residual effect of organic sources on straw yield. The SWS showed higher residual effect on uptake of N, K, Mn, Zn and Cu, while SWC ranked second in uptake on N, Zn and Mn. The SWS was as good as SWC in respect of K and Cu uptake and was as good as PM in respect of P uptake. The SWC recorded lower P and Fe uptake than PM. The AY application showed higher residual effect on all nutrient uptake, the EY SWS being superior. The SWS increased crude protein content of wheat grain. The organic sources showed similar effect on crude fibre content and no effect on crude fat content of wheat grain was observed. The EY application was found better than AY, TY applications in respect of crude protein. The EC of soil was found to have increased by application of SWS and SWC. The SWS showed higher build up of organic carbon, P and K. The highest build up of available N was found in PM followed by SWS. The EY SWC and EY SWS increased EC, available P and Fe content of soil. The SWS increased EC, cations, anions in SPE of soil, while SWC ranked second in respect of HCO_3^- concentration and was as good as SWC and PM in respect of SO_4^{2-} and Ca^{2+} + Mg^{2+}, respectively. Although SWS and SWC improved hydraulic conductivity (HC) and infiltratiion rate (IR) over control, the effect of SWC, PM and FYM on stability of aggregates was comparable and SWS showed no effect. The EY application improved infiltration rate and decreased bulk density.

Shinde *et al.* (1995a) found that SWS and SWC without NPK showed poor nitrogen mineralization and application of NPK with these product was essential. The nitrogen mineralization pattern of compost prepared from different proportions of spent wash with press mud (SWC) and spent slurry (SSC) was studied in Sawargaon soil series by Patil and Shinde (1995b) and was compared with spent wash liquid (SWL), lagoon dried spent wash solids (SWSL), press mud (PM) and FYM. They noted the highest mineralization rate in SWS, while PM was as good as control. The rate of nitrification of all composts was found between SWSL and PM. Composting of PM with spent wash/spent slurry improved nitrification of PM. However, all compost found inferior to FYM and SWSL. The highest nitrification was noted at 45th day in SWSL and FYM. It was however, at 68th day in case of compost indicating delayed nitrification in compost.

Patil and Shinde (1995c) from green house and laboratory experiment observed higher CO_2 evolution in case of spent slurry-press mud and spent wash-press mud and spent wash solids than FYM. Decreased in yield of maize by compost application compared with FYM was also noted. The decrease in yield was attributed by them to higher CO_2 evolution affecting root growth resulting in lower uptake of nutrients.

2.7 Effect of nutrients and FYM combination on nutritive value of crops

Quality of any food grain is a complex phenomenon as it may involve several factors and may be considered from several angles and for various purposes for which the grain is utilised. Our discussion in this chapter, however, will be limited to a broad aspect of proximate composition that is crude protein, crude fat, crude fibre, etc.

A field experiment was conducted by Survase (1986) to study the effects of calcium, sulphur and boron application @ 60.0, 60.0 and 0.92 kg ha^{-1}, respectively, with and without FYM on the growth, yield, quality and nutrient uptake by groundnut in lateritic soil. The magnitude of crop response was maximum when the nutrients were applied in combination than in their straight application. An application of calcium, sulphur, boron alongwith FYM produced maximum dry pod yield (22.5 q ha^{-1}). The oil and protein content also increased due to different treatment from 44.71 to 47.61 per cent and from 24.46 to 27.24 per cent, respectively. At maximum flowering, the mean concentration of different nutrients in plants was observed in decreasing order as N (2.70 %), K (2.28 %), Ca (1.32 %). Mg (0.48 %), S (0.33 %) and P (0.21 %) which were in the ratio of 1.0 : 0.86 : 0.49: 0.81: 0.21: 0.08, respectively. The calcium sulphur and boron application showed their synergistic influence upon the uptake of macronutrients by the groundnut crop.

Duraisamy (1987) reported that N, K and farm compost application influenced the cane and sugar yield, while P had no effect. Quality parameters viz., purity, sucrose and commercial cane sugar were favourably improved by the addition of K. Nitrogen addition at lower levels slightly increased the CCS per cent, whereas other parameters were not altered. Phosphorus and farm compost application had not exerted any influence on quality.

Singh *et al.* (1988) conducted field experiment on *Mentha avensis* L. planted in July and revealed that per cent increase of 14-300 in herb, 56-230 in oil, 75-118 in sucker and 45-175 in net income was obtained when crop was given 40 t FYM + 120 kg N ha^{-1}. Application of FYM alone even upto 40 t ha^{-1} did not increase significantly the yield of herb and oil. However, sucker yield was 45 per cent more than control. Application of P and K could be totally omitted if the crop was given 40 t FYM ha^{-1} alongwith 120 kg N ha^{-1}.

Ogbadu (1989) investigated the influence of both inorganic and organic fertilizers on the chemical composition of three cultivars of field grown eggplant fruits and found that the fertilizer application significantly reduced the moisture content of the cultivars, while crude fibre, titrable acidity and total protein content were significantly increased with the exception of the Samaru stripe cultivar. Fertiliser application caused a significant decrease in the nitrate-nitrogen content of the cultivar. Significant increase in ascorbic acid content as a result of fertilizer application was observed in the Samaru stripe and Baluro cultivars but not in the white large cultivar. The beta - carotene was not detected in any of the cultivar. Calcium ammonium nitrate (CAN) and nitrogen- phosphorus potassium (NPK) fertilizer caused significant decrease in the soluble carbohydrates, while the hemicellulose content of the cultivar was significantly decreased by poultry manure application.

Grever *et al.* (1989) conducted experiment in 1980-82 on leached chorozen at Gramada, wheat was grown in a six crop rotation under irrigation with different rates of mineral and organic/mineral fertilizer. The optimum rates were 160 kg N, 120 kg P and 120 kg K/ha (5.46 - 5.51 t grain/ha) and maximum yield were 5.64 - 5.79 t grain/ha with 240 kg N, 180 kg P and 120 kg K/ha. Application of 45 t FYM ha^{-1} every 6 years usually gave slight increases in yield. The NPK use efficiency was inversly proportional to rates applied. The beneficial effect of fertilizers on 1000-grain weight and flour strength was modified by weather condition. Grain protein content was the highest at higher NPK rate.

Belhekar (1995) studied the effect of SWS and PMC on proximate composition of sorghum fodder and found that the SWS and PM increased the crude protein content of sorghum fodder, all sources decreased soluble carbohydrate and increased the ash contents of fodder.

Gawande (1995) studied the effect of SWS on wheat grain protein. The SWS increased crude protein content of wheat grain. The organic sources showed similar effect on crude fibre content and no effect on crude fat content of wheat grain was observed.

The review of literature revealed that many workers have used spent wash directly for crop production particularly for sugarcane. The information on use of spent wash solids

(SWS) and spent wash-press mud compost (SWC) in crop production is meagre, since it is the new development in the field of spent wash disposal. Whatever reports described in this chapter are concerning with the present long term experiment. Similarly the information on effect of organic sources on proximate composition of crops is also meagre.

Material and Methods

3. MATERIALS AND METHODS

A long term field experiment was started from the year 1990-91 to study the effect of spent wash solids (SWS) spent wash-press mud compost (SWC) and their interval of application on yield, nutrient uptake by sorghum (fodder)-wheat grown in sequence and on soil properties at Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri. This was the sixth year of the long term experiment (1995-96). The results of residual effect on subsequent wheat crop grown during sixth year is included in this chapter.

The spent wash compost (SWC) is prepared by the sugar factories with attached distilleries on a large scale as practical disposal method of spent wash to prevent pollution in the vicinity of sugar factories. The SWC is supplied to the member farmers of the co-operative sugar factories at concessional rates for application as manure for the crops like sugarcane, wheat, etc. Normally a dose of 20 t ha^{-1} of compost is recommended for sugarcane but the SWS available to meet the entire demand at the normal rate is less. A survey conducted by Department of Agricultural Chemistry and Soil Science, MPKV, Rahuri (unpublished data) revealed that the factories are supplying about 7 to 8 tonnes of SWC to the farmers. In the present investigation a dose of 15 t ha^{-1} of SWC was used for the first crop of sorghum. The intention was that even if a farmer uses available SWC on a small area thereby causing application at double the rate i.e. 15 - 16 t ha^{-1} the effect hazardous or otherwise on soil properties and crops grown in sequence can be assessed. In this field experiment the approach was based on actual field conditions obtained on the farmers field and was problem solving one.

3.1 Materials

3.1.1 Soil

The soil where a field experiment was conducted belonged to Sawargaon series and was classified as fine montmorillonitic, isohyperthermic family of Vertic Ustropept.

Since this is a long term experiment started from the year 1990-91, the representative surface soil sample from the plot was collected by Patil (1991) from 0-15 cm depth before sowing of the experiment during the first year. The orginal soil sample collected before start of the experiment was not available for analysis. The sample was dried under shed, powdered in wooden mortar and pestle and sieved through 2 mm sieve (nylon netted) and analysed by Patil (1991). The physical and chemical properties of soil as noted by Patil (1991) are reported in Table 2.

3.1.2 Organic sources

Organic sources used for the first crop of sorghum during the sixth year of the experiment were as under :

Table 2. Physical and chemical properties of soil before start of the long term experiment

Soil property	Value
I) Physical	
1. Partical size ditribution	
a) Sand (%)	19.15
b) Silt (%)	42.55
c) Clay (%)	38.30
2. Textural class	clay loam
3. Hydraulic conductivity (cm h^{-1})	0.96
4. Bulk density (Mg m^{-3})	1.38
5. Void ratio	0.92
6. Porosity	0.48
7. Aggregate stability (MWD mm)	0.33
8. Infiltration rate (cm h^{-1})	3.38
II) Chemical	
1. pH (1:2.5 soil : water)	8.70
2. EC (1:2.5 soil : water) (dS m^{-1})	0.21
3. Organic carbon (%)	0.54
4. Available nitrogen (kg ha^{-1})	222
5. Available phosphorus (kg ha^{-1})	7.6
6. Available potassium (kg ha^{-1})	420
7. DTPA extractable micronutrients	
a) Iron (mg kg^{-1})	10.0
b) Manganese (mg kg^{-1})	24.7
c) Zinc (mg kg^{-1})	0.42
d) Copper(mg kg^{-1})	2.28

(Patil, 1991)

1. **Spent wash solid (SWS) :** was obtained from Rahuri Sahakari Sakhar Karakhana Limited., Shrishivajinagar Tahsil Rahuri, Dist. Ahmednagar, Maharashtra State. The lagooning method of disposal of spent wash is adopted by the factory. The sun-dried spent wash solids were collected from the lagoons.

2. **Spent wash-press mud compost (SWC) :** was obtained from Malegaon Sahakari Sakhar Karakhana Limited, Malegaon (Shivnagar), Tahsil Baramati, District Pune, Maharashtra State. The method of preparation is described by Patil (1991) given under sub-head 2.5.

3. **Press mud (PM):** was obtained from Malegaon Sahakari Sakhar Karkhana Limited, Malegaon (Shivnagar), Tahsil Baramati, District Pune, Maharashtra State. The factory adopted the double sulphitation process for sugar manufacture.

4. **Farmyard manure (FYM):** was obtained from Research-cum-Development Project on Cattle, MPKV, Rahuri, District Ahmednagar, Mahrashtra State.

The composition of organic sources used for the first crop of sorghum in the investigation are given in Table 3.

3.1.3 Fertilizers

Commercial grade urea (46.0% N), single super-phosphate (7.04% P) and muriate of potash (49.8% K) were used

Table 3. Composition of organic sources used

S.N.	Particular	SWS	PM	SWC	FYM
1.	pH (1:10)	6.70	7.40	8.20	7.40
2.	EC (1:10) dS m^{-1}	7.55	3.75	7.25	4.42
3.	Organic carbon (%)	33.06	37.12	31.90	34.22
4.	Nitrogen (%)	1.95	1.24	2.13	1.39
5.	Phosphorus (%)	0.40	2.84	1.11	1.31
6.	Potassium (%)	5.30	0.72	2.02	1.40
7.	Calcium (%)	3.75	6.50	4.00	2.50
8.	Magnesium (%)	0.75	0.45	0.90	0.75
9.	Sodium (%)	0.62	0.25	0.44	0.56
10.	Sulphate (%)	5.90	2.70	3.00	2.20
11.	Chloride (%)	0.28	1.54	1.17	0.84
12.	Iron (mg kg^{-1})	8325	12725	12175	13500
13.	Manganese (mg kg^{-1})	100	250	400	250
14.	Zinc (mg kg^{-1})	140	197	202	180
15.	Copper (mg kg^{-1})	135	75	125	105
16.	C : N ratio	16.95	29.93	14.97	24.60

(This composition of organic sources applied to sorghum crop).

to supply N, P and K, respectively and were obtained from Rahuri market.

3.1.4 Seed

The thiram treated seed of wheat variety HD2189 was obtained from Directorate of Farms, Mahatma Phule Krishi Vidyapeeth, Rahuri, District Ahmednagar, Maharashtra State.

3.2 Details of conduct of field experiments

3.2.1 Experimental details

A field experiment was laid out in split plot design with following treatments which were replicated three times.

3.2.1.1 Treatments

I. Main-treatments : Organic sources

1. No organic source, control (CK)
2. Spent wash solids i.e. lagoon dried spent wash (SWS)
3. Press mud (PM)
4. Compost prepared from spent wash and press mud in 2 : 1 proportion (SWC)
5. Farmyard manure (FYM)
   Organic source were applied at the rate of 15 t ha^{-1} to the first crop of sorghum (fodder).

II. Sub-treatments : Interval of application

1. Every year (EY)
2. Alternate year (AY)
3. After two year (TY)

In *kharif* season, sorghum crop for fodder was taken. Every year the materials in treatments 2 to 5 were applied just before sowing of sorghum and were not applied to subsequent crop of wheat taken in *rabi* season.

3.2.1.2 General information

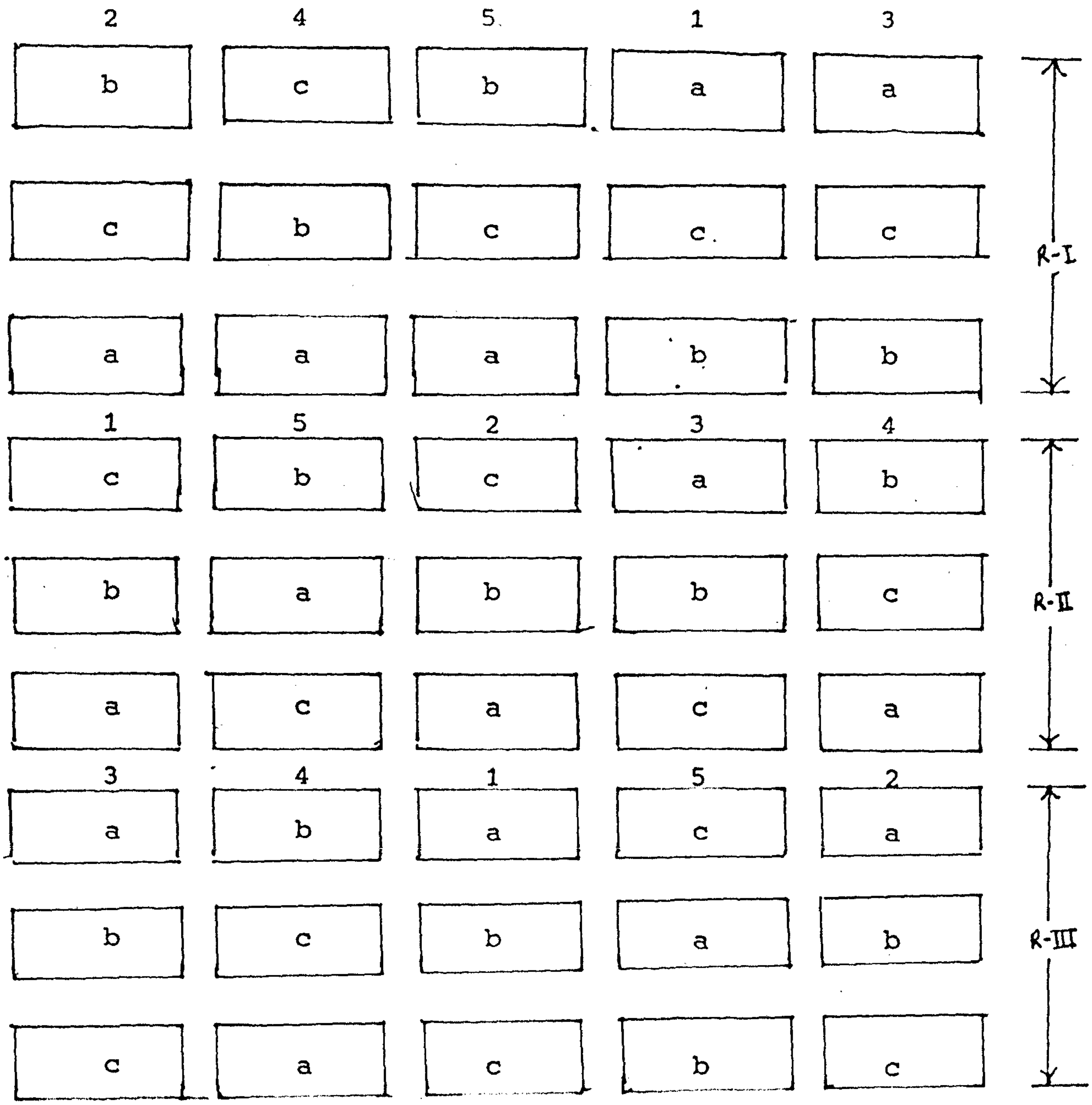
			Wheat
Plot size	Gross	:	7 m x 5 m
	Net	:	6 m x 4 m
Spacing		:	22.5 cm
Seed rate		:	100 (kg ha^{-1})
Variety		:	HD-2189
Fertilizer dose		:	
Nitrogen		:	120 kg N ha^{-1}
Phosphorus		:	60 kg P_2O_5 ha^{-1}
Potassium		:	60 K_2O ha^{-1}
Date of sowing		:	29.11.1995
Date of harvesting		:	20.03.1996

The original layout plan (split plot) of long term experiment is given in Fig. 1.

3.2.2. Details of field operations

3.2.2.1 Tillage operations

Before sowing of wheat, the field was ploughed and disced and flat beds of size 7 m x 5 m were prepared. The beds were levelled properly for wheat. Every care was taken to keep the layout intact.



Design : Split plot

Replication : Three

Plot Sizes

Gross : 7.0 x 5.0 m^2

Net : 6.0 x 4.0 m^2

Main treatments

1. Control
2. SWS
3. PM
4. SWC
5. FYM

Sub-treatments

a : EY

b : AY

c : TY

Fig.1 : Layout Plan of Long Term Experiment

3.2.2.2 Application of organic sources to first crop of sorghum

Details of application of organic sources as per sub-treatments from first to sixth year of experimentation are given below :

Year	Subtreatments EY	AY	TY
1990 - 91	A	A	A
1991 - 92	A	NA	NA
1992 - 93	A	A	NA
1993 - 94	A	NA	A
1994 - 95	A	A	NA
1995 - 96	A	NA	NA

A = Applied, NA = Not applied

Since this was the sixth year of the experimentation organic sources were applied to EY sub-treatments only during first sorghum crop. Thus, there were six applications to EY sub-treatment plots, while three applications to AY sub-treatment plots and two application to TY sub-treatment plots. After sorghum crop, wheat was grown to study the residual effect and therefore, organic sources were not applied.

3.2.2.3 Application of fertilizers

For wheat, the half dose of N was applied just before sowing and remaining half dose of N one month after sowing and full dose of P and K was applied just before soiwng of wheat. The N was applied through Urea, P through single superphosphate and K through muriate of potash. The fertilizers were applied in the lines made with a marker in the plots and subsequently covered with inverted marker.

3.2.2.4 Sowing

The calculated quantity of wheat seeds (350 g) per plot were sown in the lines marked with a marker at 22.5 cm apart. The plots were irrigated and wheat was sown at field capacity condition.

3.2.2.5 Interculturing

The three hand weedings were carried out.

3.2.2.6 Irrigation

Wheat was irrigated timely during its growth and six irrigations were applied to wheat crop.

3.2.2.7 Plant protection

Wheat crop was sprayed with endosulphan (15 mL in 10 L water) and dithane M-45 (15 g in 10 L water) as protective measure against pests and diseases, respectively.

3.2.3 Soil and plant sampling

3.2.3.1 Soil

Representative surface soil samples (0-15 cm) were collected from each plot before sowing and after harvest of wheat. The samples were dried under shed and ground in wooden mortar and pestle and sieved through 2 mm sieve (nylon netted). Physical properties such as infiltration rate, hydraulic conductivity, bulk density and water stable aggregates of soil were determined after harvest of wheat. The chemical properties viz., pH, EC, organic carbon, available N, P, K, DTPA - Fe, Mn, Zn and Cu and heavy metals like Co, Ni, Cd and Cr were determined before sowing and after harvest of wheat. After harvest of wheat the soil saturation paste extract was prepared which was analysed for pH, EC, cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anions (CO_3^{2-}, HCO_3^{-}, Cl^{-} and SO_4^{2-}).

For determination of water stable aggregates the soil samples after harvest of wheat were ground and sieved through 4 mm sieve and used. For other physical properties of 2 mm sieved soil was used execpt for bulk density where soil clods of greater than 2 cm diameter were used. The infiltration rate was determined after harvest of wheat *in situ*. For determination of chemical properties before sowing of wheat and after harvest of wheat, the 2 mm sieved soil samples were used.

3.2.3.2 Plant

Plant samples were collected at tillering, flag leaf and harvest stages. They were cleaned and dried under shade and subsequently in an oven at 70oC temprature and pounded in wooden mortar and pestle.

The samples were analysed for concentration of N, P, K, Fe, Mn, Zn, Cu from which the uptake was calculated. The samples were also analysed for crude fat, crude proteins and crude fibre.

3.2.4. Meteorological observations

So as to get idea about climate during the experimental period week-wise meteorological observations recorded from May 1995 to March 1996 in respect of temperature, humidity, rainfall and rainy days and are given in Table 4.

3.3 Methods

Methods used for soil and plant analysis are given below :

3.3.1 Soil analysis

3.3.1.1 Physical properties

1. **Hydraulic conductivity :** The hydraulic conductivity of the disturbed soil sample was measured by constant head method as described by Klute and Dirksen (1986) using formula :

$$K = \frac{VL}{At\ (H + L)}$$

where,

V = Volume of water flow (cm^3)

L = Length of soil column (cm)

Table 4. Meteorological data from May 1995 to March 1996

Month	Meteoro logical week	Temperature 0°C		Relative humidity (%)		Rainfall (mm)	Rainy days
		Maximum	Minimum	Morning	Evening		
1	2	3	4	5	6	7	8
May 95	19	37.9	23.9	70	32	4.5	1
	20	37.1	22.2	77	30	0.0	0
	21	37.1	21.4	76	27	6.5	1
	22	40.0	25.4	68	22	0.0	0
June 95	23	39.2	22.8	68	31	0.0	0
	24	36.9	24.1	78	40	2.3	0
	25	34.7	24.1	76	48	50.0	1
	26	31.2	23.7	84	63	7.1	2
July 95	27	34.0	23.5	83	44	11.6	2
	28	32.1	23.4	84	59	52.3	1
	29	28.3	23.1	82	70	9.7	2
	30	29.5	22.7	80	67	7.2	1
	31	31.1	23.0	83	61	9.2	2
Aug 95	32	31.9	22.6	79	52	15.0	1
	33	31.8	21.4	83	46	0.0	0
	34	33.5	21.3	87	43	13.1	1
	35	31.0	22.7	90	75	117.4	5
Sept 95	36	29.9	20.8	88	56	27.2	3
	37	30.5	21.9	89	65	58.9	2
	38	32.1	20.2	81	49	3.4	1
	39	31.1	21.5	81	57	67.0	3
Oct 95	40	32.8	21.2	87	52	26.4	3
	41	31.3	20.8	87	60	23.7	3
	42	29.9	20.1	85	61	80.2	4
	43	30.5	14.9	77	36	0.0	0
	44	30.5	12.7	70	28	0.0	0
Nov 95	45	29.6	11.2	62	30	0.0	0
	46	30.2	11.7	65	29	0.0	0
	47	29.5	13.3	71	43	0.0	0
	48	30.0	13.4	78	44	0.0	0

Table 4. Contd....

1	2	3	4	5	6	7	8
Dec 95	49	29.7	10.6	79	36	0.0	0
	50	29.7	9.6	79	28	0.0	0
	51	30.2	10.8	77	31	0.0	0
	52	28.7	12.2	85	38	0.0	0
Jan 96	1	29.1	14.2	85	42	0.0	0
	2	29.3	12.2	83	45	0.0	0
	3	29.2	10.2	85	44	0.0	0
	4	30.8	11.6	82	35	0.0	0
	5	32.3	11.9	76	31	0.0	0
Feb 96	6	31.3	12.6	73	28	0.0	0
	7	31.0	12.6	75	38	0.0	0
	8	30.0	12.7	71	24	0.0	0
	9	33.9	12.9	73	26	0.0	0
Mar 96	10	34.6	13.1	68	23	0.0	0
	11	37.3	19.5	70	33	0.0	0
	12	36.4	17.6	64	19	0.0	0
	13	38.5	16.3	62	18	0.0	0
Total						606.2	39

A = Area of core or pipe, r^2 (cm^2)

r = Radius of core or pipe (cm)

H = Height of core or pipe (cm)

t = Time (h)

2. **Bulk density** : Bulk density was determined by clod sample method as described by Blake and Hartge (1986). It was calculated by using formula :

$$\text{Bulk density } (\text{Mg m}^{-3}) = \frac{\text{Mass (Mg)}}{\text{Volume } (\text{m}^3)}$$

3. **Infiltration rate** : This was determined in the field after harvest of wheat by using double ring infiltrometer as described by Bouwer (1986).

4. **Water stable aggregates** : The mean weight diameter (mm) was determined by using Yoder's apparatus as described by Richards (1968).

3.3.1.2 **Chemical properties**

1. **pH** : The pH of soil was measured by using potentio-meter as outlined by Mclean (1982). The soil-water ratio used was 1:2.5.

2. **Electrical conductivity (EC)** : The EC was measured by conductometric method as described by Rhoades (1982). The suspension used for pH measurement was filtered and then used for measuring the EC.

3. **Organic carbon** : It was determined by the Walkley and Black method using ferroin indicator as described by Nelson and Sommers (1982).

4. **Available nitrogen** : The alkaline permanganate method of Subbiah and Asija (1956) was used.

5. **Available phosphorus** : It was determined by Olsen method for which the soil was extracted by 0.5 M $NaHCO_3$ (Olsen and Sommers, 1982) and phosphorus determined by using ascorbic acid on Spectronic-20 as described by Watanabe and Olsen (1965).

6. **Available potassium** : It was determined by using neutral normal ammonium acetate extractant on Flame-photometer as described by Knudson et al. (1982).

7. **Available micronutrients** : Available micronutrients (Fe, Mn, Zn and Cu) in soil were extracted by using 0.005 M DTPA (Diethylene triamine penta acetic acid) + 0.01 M $CaCl_2$ + 0.1 M triethanolamine (pH 7.3) (Lindsay and Norvell, 1978). The DTPA extractable Fe, Mn, Zn and Cu were estimated on Atomic Absorption Spectrophotometer (AAS), Perkin Elmer, model 2380) on oxyacetylene flame. The same extract is used for determination of heavy metals such as Cd, Co, Ni and Cr in the soil on AAS.

3.3.1.3 Saturation paste extract of soil

The saturation paste extract (SPE) of soil was obtained by following the method described by Richards (1968).

1. **pH** : The pH of the extract was measured by using potentiometer as outlined by Mclean (1982).

2. **Electrical conductivity** : The EC of the extract was measured by conductometric method as described by Rhoades (1982).

3. **Cations** :

a) **Calcium + Magnesium** : Calcium + Magnesium in the SPE was determined by using Versenate method as described by Lanyon and Heald (1982).

b) **Potassium and sodium** : Potassium and sodium in SPE were determined on Flame photometer as described by Richard (1968).

4. **Anions** :

a) **Carbonate and Bicarbonate** : Carbonate and bicarbonate in the SPE were determined by method described by Richards (1968).

b) **Chorides** : The chorides in the SPE were determined by electrometric titration of chlorides with Std $AgNO_3$ using potassium chromate indicator after CO_3 and HCO_3 determination as described by Richards (1968).

c) **Sulphates** : Sulphates in the SPE were determined by turbidimetry method using $BaCl_2$ as described by Ghosh *et al.* (1983).

3.3.2 Plant analysis

The plant samples of wheat (grain and straw) were digested in H_2SO_4 and H_2O_2 (1:1) mixture as per the method of Parkinson and Allen (1975). This extract was used for N, Fe, and K determinations.

The plant samples were also digested in $HNO_3:HClO_4$ (4:1) (Johnson and Ulrich, 1959) and the extract was used for P and micronutrient determinations (except Fe).

1. **Total Nitrogen** : It was determined in H_2SO_4 : H_2O_2 extract by Micro-kjeldahl method as described by Keeney and Nelson (1982).

2. **Total phosphorus** : It was determined in HNO_3 : $HClO_4$ extract using the Vanadomolybdate yellow colour method as described by Jackson (1967).

3. **Total potassium** : It was determined in H_2SO_4 : H_2O_2 extract on Flame-photometer.

4. **Micronutrients** : Mn, Zn and Cu were determined in HNO_3 : $HClO_4$ extract and Fe in H_2SO_4 : H_2O_2 extract on the Atomic Absorption Spectrophotometer, make Perkins Elmer model 2380 on oxyacetylene flame.

5. **Heavy metals** : The same aliquat is used for determination of heavy metals like Co, Cd, Ni and cr on Atomic Absorption Spectrophotometers, made Perkins Elmer Model-2380 on oxyacetylene flame.

6. **Wheat grains samples** were also analysed for crude fat, crude protein, crude fibre (AOAC, 1975).

a) **Moisture** : It was determined gravimetrically

b) **Crude fat** : It was determined by using Soxhlet apparatus using petroleum ether.

c) **Crude protein** : Plant sample digested in H_2SO_4 : H_2O_2 used for the determination of nitrogen. The per cent nitrogen was multiplied by 5.75 to get per cent crude protein (Tkachuk, 1969).

d) **Crude fibre** : The defatted sample (from crude fat determination) was boiled in dilute H_2SO_4 (0.25N) and subsequently in dilute NaOH (0.31N) and passed through muslin cloth. The residue obtained was dried weighed and ignited and again weighed. From loss in weight the crude fibre was calculated.

e) **Carbohydrates** : It was obtained by difference 100 - (% moisture + % crude fat + % crude protein + % crude fibre + % ash).

3.4 Statistical analysis

The data obtained on physical and chemical properties of soil and concentration and uptake of nutrients by plants were analysed by using split plot analysis procedure as given by Panse and Sukhatme (1967). The data of three replications have been averaged and average values are presented in the following chapter.

Results and Discussion

4. RESULTS AND DISCUSSION

A long term field experiment was started during the year 1990-91 to study the effect of spent wash solids (SWS) and spent wash-press mud compost (SWC) and their interval of application on i) yield and nutrient uptake by sorghum and wheat grown in sequence and ii) soil properties after harvest of sorghum and wheat crops at Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri using split plot design and three replications. This was sixth year of the long term experiment (1995-96). Results of residual effect of sixth year application of organic sources on yield and nutrient uptake by wheat and on soil properties after harvest of wheat are described and discussed in this chapter.

4.1 Residual effect of spent wash solids and spent wash -press mud compost on yield, nutrients uptake by wheat and on physical and chemical properties of soil after harvest of wheat

4.1.1 Fertility status of soil before sowing of wheat (after harvest of sixth year sorghum)

The data on fertility parameters of soil before sowing of wheat are presented in Table 5. The effect of organic sources on pH and available N was not significant, similarly, effect of interval of application on pH, organic

Tabel 5. Fertility status of soil before sowing of wheat

	pH	Ec (dS m^{-1})	Organic carbon (%)	Available nutrients						
				N	P	K	Fe	Mn	Zn	Cu
				kg ha^{-1}			mg kg^{-1}			
Organic sources (A)										
CK	8.45	0.127	0.67	198	15.5	347	7.3	9.3	0.40	1.92
SWS	8.33	0.178	0.74	209	20.2	614	9.3	11.5	0.59	2.52
PM	8.34	0.146	0.84	229	25.5	535	8.7	10.6	0.58	2.38
SWC	8.34	0.139	0.84	198	26.5	425	8.8	10.8	0.60	2.01
FYM	8.43	0.138	0.85	196	23.9	586	9.4	10.8	0.59	2.17
SEm ±	0.03	0.005	0.011	35	1.6	19	0.07	0.1	0.007	0.07
CD 5%	NS	0.015	0.04	NS	5.3	64	0.22	0.5	0.02	0.22
Interval of application (B)										
EY	8.41	0.127	0.79	209	21.4	515	9.0	11.3	0.64	2.42
AY	8.35	0.149	0.78	204	22.8	502	8.8	10.5	0.56	2.19
TY	8.35	0.229	0.79	205	22.8	488	8.3	10.07	0.45	1.99
SEm ±	0.019	0.006	0.016	27	1.33	9	0.06	0.08	0.02	0.04
CD 5%	NS	0.019	NS	NS	NS	NS	0.18	0.26	0.06	0.12
Interaction										
A x B										
SEm ±	0.043	0.015	0.036	62	2.99	21	0.136	0.19	0.037	0.093
CD 5%	NS	NS	NS	NS	NS	NS	0.40	0.57	0.108	NS
B x A										
SEm ±	0.048	0.013	0.031	62	2.93	26.29	0.13	0.22	0.031	0.10
CD 5%	NS	NS	NS	NS	NS	NS	0.38	0.69	0.091	NS

NS = Not significant.

carbon available N, P and K was not significant. So also the interaction effect on all the parameters except available Fe, Mn, Zn was not significant.

Application of SWS increased significantly the electrical conductivity over all other organic sources. It also helped to build up the available micronutrient content in the soils except available Zn which was at par with other source. The effect of SWC was as good as FYM in respect of EC, organic carbon, available Mn, Zn and Cu. The highest build up of organic carbon was found in FYM treatment which was at par with SWC and PM. All the three treatments were found significantly superior to SWS in this respect and highest available built up of P was found in SWC which was significantly better than SWS and was at par with PM and FYM, the last two treatments being at par in this respect.

Application of organic sources resulted in higher EC (except FYM), organic carbon, available P and available micronutrients than control.

Every year application of organic sources helped to build up available micronutrient content in soil which was followed by alternate year and after two year of applications of organic sources.

4.1.2 Residual effect on concentration of nutrients in wheat plant at tillering stage

The data obtained on concentration of nutrients are presented in Table 6.

Effect of interval of application on Mn concentration and interaction effect on concentration of all the nutrients except potassium and zinc concentration was not significant.

4.1.2.1 Nitrogen

Application of all the organic sources resulted in higher nitrogen concentration than control. The SWS increased nitrogen concentration significantly compared with PM, FYM and SWC. This treatment was followed by PM, which was at par with FYM. Both the treatments were found better than SWC in this respect. The highest nitrogen concentration was found in EY application treatment. The value was significantly higher than AY and TY applications, the last two treatments being at par.

4.1.2.2 Phosphorus

The PM showed the highest value of P concentration (0.086%) and was significantly higher than other sources. The PM was followed by SWS (0.060%) which was at par with FYM

iv) Iron (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	170	240	236	233	210	217	4	12
AY	119	197	219	211	189	187		
TY	132	190	211	203	169	140		
Mean	140	209	221	215	189			

		Interaction	SEm ±	CD 5%
SEm ±	12	A x B	9.01	NS
CD 5%	38	B x A	13.75	NS

v) Manganese (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	13	25	19	21	20	20	0.64	NS
AY	12	25	18	20	19	19		
TY	14	22	17	18	18	18		
Mean	13	24	18	20	19	19		

		Interaction	SEm ±	CD 5%
SEm ±	0.7	A x B	1.44	NS
CD 5%	2.0	B x A	1.36	NS

vi) Zinc (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	39	128	51	153	136	101	2.86	8
AY	33	130	34	129	59	77		
TY	31	103	30	73	40	56		
Mean	35	121	39	118	78			

		Interaction	SEm ±	CD 5%
SEm ±	6	A x B	6.40	18
CD 5%	20	B x A	8.23	25

vii) Copper (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	20	29	27	28	29	27	0.51	1.5
AY	18	26	24	26	27	24		
TY	16	25	23	22	22	22		
Mean	18	26	24	25	26			

		Interaction	SEm ±	CD 5%
SEm ±	0.6	A x B	1.14	NS
CD 5%	2.0	B x A	1.15	NS

(0.053%) and SWC (0.049%). The EY and AY applications were on par and both being significantly better than TY application in this respect.

4.1.2.3 Potassium

All organic sources resulted in higher K concentration than control. The highest value was found in SWS (3.08%) which proved significantly better than all other sources. The PM, SWC and FYM were at par with each other. The EY application proved significantly better than AY application which was also found significantly better than TY application.

The EY SWS was on par with AY SWS and proved better than TY SWS. The EY SWS, AY SWS and TY SWS showed higher values than their respective application of other sources.

4.1.2.4 Iron

All organic sources showed higher Fe content than control. The sources, however, did not differ significantly from one another. The Fe concentration in EY application was significantly greater than AY application both treatments found significantly better than TY application.

4.1.2.5 Manganese

All organic sources showed higher Mn concentration than control. The SWS recorded the highest Mn concentration and proved significantly better than other sources.

4.1.2.6 Zinc

The highest zinc concentration was found in SWS treatment which was however, at par with SWC and both the treatments showed significantly higher values than other sources. The PM treatment was as good as control. The EY application was significantly superior to AY and TY applications, the AY being better than TY application.

The EY SWC and AY SWC were on par however, EY SWC showed higher value than TY SWC. All the EY organic sources showed higher values than TY organic sources.

4.1.2.7 Copper

All organic sources resulted in higher Cu content than control. The sources were at par with each other.

Results showed that the wheat plants in SWS treated plots were significantly better in respect of N, K and Fe concentration than other sources. It might be because of the

SWS treated plots showed higher values of these nutrients before sowing of wheat. The plants in SWC treated plots were as good as SWS in Zn nutritional status. The Fe nutritional status of plant in PM was as good as SWS and SWC. The nutritional status of PM treated plot plants were superior to other sources in respect of P. Although the PM treated plots showed lower available P value than other sources it has resulted in higher P concentration than other sources indicating better availability of P during the course of plant growth. The P nutritional status of SWS and FYM and SWC and FYM was not significantly different. The Mn and Cu status was almost similar in all organic sources treated plot, as all sources treated plots did not differ much in respect of available Mn and Cu content of soil before sowing of wheat.

The N concentration and P concentration in EY and AY was similar but better than TY application. The K, Fe, Mn and Zn nutritional status in plants of EY application plots was found better than AY application and the AY application was also found better than TY applications.

By and large EY application of SWS proved better in respect of N, K, Zn nutritional status of plants.

4.1.3 Residual effect on concentration of nutrients in wheat plants at flag leaf stage

Data obtained on concentration of nutrients at flag leaf stage are presented in Table 7. The effect of interval of application on Mn concentration and interaction effect on N, Mn and Cu concentration was not significant.

4.1.3.1 Nitrogen

The effect of organic sources of N concentration showed following trend : SWS > PM = FYM > SWC > CK and in interval of application the trend was : EY > AY = TY.

4.1.3.2 Phosphorus

The organic sources resulted in higher P concentration in PM (0.110%) treatment which was found superior to SWS (0.099%), both being superior to FYM (0.076%) and SWC (0.062%). However, the FYM was superior to SWC and CK. The EY application was superior to AY and TY applications.

The EY PM was superior to all other EY treatments. The EY SWS was superior to EY FYM and EY SWC. The latter two were on par. The AY PM and AY SWS were at par and found superior to AY SWC and AY FYM. All AY organic sources treatments were superior to TY organic sources treatments.

Table 7. Residual effect of spent wash solids and spent wash - press mud compost and their interval of application on nutrient concentration at flag leaf stage of wheat

i) Nitrogen (%)

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	1.78	2.75	2.51	2.33	2.37	2.34	0.030	0.088
AY	1.50	2.51	2.19	2.02	2.20	2.08		
TY	1.40	2.45	2.12	1.87	2.17	2.00		
Mean	1.56	2.57	2.27	2.07	2.24			

		Interaction	SEm ±	CD 5%
SEm ±	0.0394	A x B	0.067	NS
CD 5%	0.13	B x A	0.067	NS

ii) Phosphorus (%)

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.045	0.107	0.127	0.075	0.083	0.087	0.001	0.003
AY	0.046	0.098	0.105	0.064	0.075	0.077		
TY	0.046	0.093	0.99	0.047	0.071	0.071		
Mean	0.045	0.099	0.110	0.062	0.076			

		Interaction	SEm ±	CD 5%
SEm ±	0.002	A x B	0.002	0.007
CD 5%	0.006	B x A	0.003	0.008

iii) Potassium (%)

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	2.08	3.20	2.71	2.80	2.82	2.27	0.02	0.08
AY	2.09	2.97	2.55	2.33	2.46	2.48		
TY	2.02	2.63	2.23	2.18	2.20	2.25		
Mean	2.06	2.93	2.63	2.43	2.49			

		Interaction	SEm ±	CD 5%
SEm ±	0.03	A x B	0.062	0.18
CD 5%	0.12	B x A	0.064	0.19

iv) Iron (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	300	446	543	466	445	440	7.75	2.28
AY	351	441	450	388	405	407		
TY	330	390	383	373	385	372		
Mean	327	425	458	409	411			

		Interaction	SEm ±	CD 5%
SEm ±	11.61	A x B	17.35	51.17
CD 5%	37.87	B x A	18.31	55.23

v) Manganese (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	60	102	110	101	100	94	3.8	NS
AY	59	90	95	90	89	84		
TY	60	87	86	81	85	80		
Mean	59	93	97	90	91			

		Interaction	SEm ±	CD 5%
SEm ±	4.2	A x B	8.5	NS
CD 5%	13.8	B x A	8.1	NS

vi) Zinc (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	136	340	176	256	251	232	3	11
AY	168	266	161	223	181	200		
TY	150	240	143	185	143	172		
Mean	151	284	160	221	191			

		Interaction	SEm ±	CD 5%
SEm ±	9	A x B	8.74	25.00
CD 5%	30	B x A	11.84	36.00

vii) Copper (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	49	69	64	60	67	61	1.638	4.83
AY	50	61	56	53	61	56		
TY	51	56	50	50	55	42		
Mean	50	62	56	54	61			

		Interaction	SEm ±	CD 5%
SEm ±	2.0	A x B	3.66	NS
CD 5%	6.0	B x A	3.52	NS

4.1.3.3 Potassium concentration

The effect of organic source on K concentration showed following trend : SWS > PM = FYM = SWC > CK and the trend in interval of application was : EY > AY > TY.

The EY SWS found better than AY SWS which was better than TY SWS. All these three treatments were superior to their respective EY, AY and TY applications of other organic sources.

4.1.3.4 Iron

The effect of organic sources on Fe concentration showed following decreasing trend PM > SWS = FYM = SWC > CK and the trend in interval of application was : EY > AY > TY.

All EY application of organic sources except PM were better than their respective AY and TY application of other organic sources.

4.1.3.5 Manganese

The effect of organic sources showed the following decreasing trend : PM = SWS = FYM = SWC > CK. All organic sources were superior to CK. These four treatments were, however, at par.

4.1.3.6 Zinc

The effect of organic sources showed following decreasing trend : SWS > SWC = FYM > PM > CK and the trend in interval of application was : EY > AY > TY.

The EY SWS was found better than AY SWS which was better than TY SWS. All these treatments proved superior to their respective AY, TY applications of other organic sources.

4.1.3.7 Copper

The highest Cu concentration was noted in SWS (62 mg Kg^{-1}). However, the SWS proved superior to SWC (54 mg Kg^{-1}). The latter was on par with PM, FYM and CK. The highest value was found in EY application (69 mg Kg^{-1}) which was superior to AY and TY application.

Results showed that the plants in SWS treated plots were nutritionally better in respect of N, P, K, Zn and Cu. However, nutritional status of plants in SWS was as good as PM treated plot plants in respect of P, Mn and Fe and with FYM treated plot plants in respect of Cu and Mn. The SWC ranked second in respect of Zn nutritional status and PM ranked second in respect of N and K nutritional status.

The EY application resulted in better nutritional status of plants in respect of K, Fe and Zn followed by AY application and the TY application showed the lowest nutritional status in these nutrients. The EY application also showed better nutritional status in respect of N than AY and TY applications. However, nutritional status of EY and AY was similar and better than TY application in respect of P and Cu concentration.

4.1.4 Residual effect on grain yields of wheat

Data on wheat grain and straw yields are presented in Table 8. The data on grain yield is also presented in Fig. 2. The effect of organic sources on straw yield, effect of interval of application on grain yield and interaction effect on grain yield were not significant.

4.1.4.1 Grain yield

The SWS recorded the highest grain yield (3.94 t ha^{-1}) which was significantly higher than all other sources. The other sources were at par with each other and were as good as control showing no residual effect on grain yield.

4.1.4.2 Straw yield

No significant effect of organic sources on straw yield was observed but in interval of application EY treatment

Table 8. Residual effect of spent wash solids and spent wash - press mud compost and their interval of application on grain and straw yields of wheat

i) Grain yield (t ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	3.34	4.13	3.99	3.91	3.62	3.80	0.13	NS
AY	3.40	4.12	3.52	3.39	3.04	3.49		
TY	3.18	3.59	2.94	3.21	3.63	3.31		
Mean	3.30	3.94	3.49	3.50	3.43			

			Interaction	SEm ±	CD 5%
	SEm ±	0.12	A x B	0.31	NS
	CD 5%	0.39	B x A	0.29	NS

ii) Straw yield (t ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	4.50	5.49	5.30	5.93	5.49	5.42	0.045	0.13
AY	5.16	5.03	5.15	5.25	5.04	5.12		
TY	5.20	4.90	4.90	5.09	5.07	5.03		
Mean	5.08	5.14	5.11	5.42	5.20			

			Interaction	SEm ±	CD 5%
	SEm ±	0.097	A x B	0.10	0.29
	CD 5%	NS	B x A	0.12	0.39

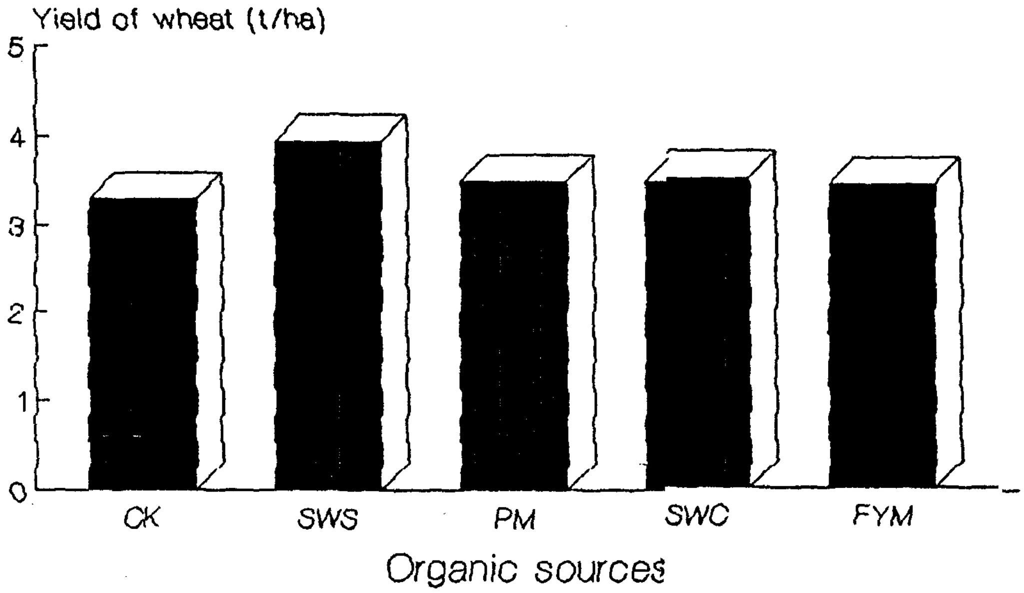


Fig.2. Residual effect of SWS, SWC and their interval of application on grain yield of wheat

showed the higher value than AY and TY applications. Among interaction effect of EY SWC showed the higher straw yield and proved better than other treatment which might be because of higher available N, P and K in SWC, treated plots before sowing of wheat.

Results obtained showed that the SWS had significant residual effect on grain yield and the EY application of organic sources proved better.

During first year of the present long term experiment, application of SWC showed significant residual effect on yield of wheat, while other sources were as good as control (Shinde et al., 1993b). The effect of organic sources on yield of wheat was not significant, while EY application of sources showed residual effect during second year (Shinde et al. 1995a). Similarly, no residual effect of organic sources was observed on wheat grain and straw yields, while residual effect on straw yield was noted in EY and AY applications by Shinde et al. (1995c) during third year of experimentation. All sources showed residual effect on grain and straw yields compared with control, however sources were at par during fourth year of application (Ove, 1995). Application of SWS, PM and SWC with NPK showed residual effect on wheat yield under pot condition (Takate, 1992). During fifth year, the SWS, SWC and PM showed residual effect on grain yield of wheat (Gawande, 1996).

4.1.5 Residual effect on concentration of nutrients in wheat grain and straw at harvest

Data on concentration of nutrients at harvest are presented in Table 9. The effect of organic sources, on Cu in grain was not significant and interaction effect on N, P concentration in straw were not significant. Similarly interaction effect on N, P, K and Cu concentration in grain and straw was not significant, so also the interaction effect on Mn concentration in grain.

4.1.5.1 Nitrogen

The nitrogen concentration in grain showed following trend : SWS > PM = FYM SWC = CK. The EY application showed higher N concentration than AY and TY applications. The TY application was at par with AY application.

The trend of N concentration in straw was : SWS = SWC > FYM = PM > CK.

4.1.5.2 Phosphorus

Organic sources showed following decreasing trend in P concentration in grain : PM = SWS = SWC > FYM > CK. The

Table 9. Residual effect of spent wash solids and spent wash - press mud compost and their interval of application on nutrient concentration in wheat grain and straw at harvest

i) Nitrogen in grain (%)

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	2.07	3.35	2.89	2.38	2.72	2.68	0.05	0.16
AY	2.12	2.81	2.37	2.12	2.41	2.36		
TY	2.16	2.61	2.27	1.97	1.14	2.23		
Mean	2.15	2.92	2.51	2.15	2.42			

		Interaction	SEm ±	CD 5%
SEm ±	0.07	A x B	0.127	NS
CD 5%	0.23	B x A	0.127	NS

ii) Nitrogen in straw (%)

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.91	2.49	1.62	1.98	1.58	1.71	0.10	NS
AY	0.89	2.00	1.44	2.07	1.53	1.58		
TY	1.07	1.35	1.16	1.48	1.22	1.51		
Mean	0.95	1.94	1.40	1.84	1.44			

		Interaction	SEm ±	CD 5%
SEm ±	0.06	A x B	0.236	NS
CD 5%	0.22	B x A	0.204	NS

iii) Phosphorus in grain (%)

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.203	0.269	0.269	0.262	0.254	0.251	0.001	0.003
AY	0.192	0.251	0.260	0.258	0.246	0.241		
TY	0.175	0.241	0.248	0.241	0.228	0.226		
Mean	0.190	0.253	0.259	0.253	0.242			

		Interaction	SEm ±	CD 5%
SEm ±	0.003	A x B	0.002	NS
CD 5%	0.009	B x A	0.003	NS

iv) Phosphorus in straw (%)

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.117	0.235	0.216	0.173	0.156	0.179	0.010	NS
AY	0.129	0.184	0.243	0.179	0.140	0.175		
TY	0.137	0.182	0.188	0.144	0.120	0.154		
Mean	0.127	0.200	0.215	0.165	0.138			

		Interaction	SEm ±	CD 5%
SEm ±	0.014	A x B	0.022	NS
CD 5%	0.045	B x A	0.023	NS

v) Potassium in grain (%)

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.207	0.510	0.400	0.490	0.450	0.410	0.010	NS
AY	0.220	0.500	0.420	0.430	0.450	0.400		
TY	0.277	0.450	0.430	0.460	0.420	0.400		
Mean	0.232	0.480	0.410	0.400	0.440			

		Interaction	SEm ±	CD 5%
SEm ±	0.01	A x B	0.023	NS
CD 5%	0.04	B x A	0.024	NS

vi) Potassium in straw (%)

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	3.17	5.17	4.78	4.53	4.49	4.42	0.15	0.44
AY	3.35	5.38	4.81	4.42	4.15	4.42		
TY	3.19	4.27	4.27	3.66	3.28	3.73		
Mean	3.23	4.96	4.62	4.20	3.97			

		Interaction	SEm ±	CD 5%
SEm ±	0.25	A x B	0.337	NS
CD 5%	0.81	B x A	0.372	NS

vii) Iron in grain (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	301	350	458	363	346	363	2.70	8.20
AY	293	320	370	345	330	331		
TY	298	297	311	303	311	304		
Mean	297	322	379	337	329			

		Interaction	SEm ±	CD 5%
SEm ±	3.9	A x B	6.21	18.3
CD 5%	12.7	B x A	6.41	19.2

viii) Iron in straw (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	333	455	550	441	441	444	5.42	16
AY	316	440	463	395	408	404		
TY	306	407	411	356	361	368		
Mean	318	434	475	397	403			

		Interaction	SEm ±	CD 5%
SEm ±	15	A x B	12	36
CD 5%	49	B x A	18	55

ix) Manganese in grain (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	64	91	70	68	67	72	2.10	NS
AY	63	85	66	63	63	68		
TY	64	71	61	63	61	64		
Mean	63	82	65	64	64			

		Interaction	SEm ±	CD 5%
SEm ±	3.45	A x B	6.70	NS
CD 5%	11.27	B x A	6.47	NS

x) Manganese in straw (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	57.33	104.33	107.66	96.33	96.33	92.39	0.74	2.19
AY	53.66	86.00	85.33	86.33	86.00	79.46		
TY	54.00	81.00	75.00	77.00	81.00	73.60		
Mean	54.99	90.44	89.33	86.55	87.77			

		Interaction	SEm ±	CD 5%
SEm ±	1.42	A x B	1.66	4.8
CD 5%	4.65	B x A	1.96	5.9

xi) Zinc in grain (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	58	183	110	138	112	120	1.33	3.93
AY	60	127	91	120	89	97		
TY	61	88	80	66	62	71		
Mean	59	132	93	108	87			

		Interaction	SEm ±	CD 5%
SEm ±	1.23	A x B	2.98	8.79
CD 5%	4.04	B x A	2.73	8.14

xii) Zinc in straw (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	141	321	153	251	241	221	4.31	12.71
AY	125	260	133	226	176	184		
TY	131	233	118	185	150	163		
Mean	132	271	134	221	189			

		Interaction	SEm ±	CD 5%
SEm ±	8.66	A x B	9.64	28.43
CD 5%	28.26	B x A	11.70	35.72

xiii) Copper in grain (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	67	72	74	67	66	69	0.6	2.0
AY	61	68	67	63	62	64		
TY	61	63	66	60	61	62		
Mean	63	67	69	63	63			

		Interaction	SEm ±	CD 5%
SEm ±	1.67	A x B	1.29	NS
CD 5%	NS	B x A	1.90	NS

xiv) Copper in straw (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	40	64	57	57	64	57	1.21	3.59
AY	42	40	48	47	56	45		
TY	43	37	43	43	52	44		
Mean	41	47	46	49	57			

		Interaction	SEm ±	CD 5%
SEm ±	2.42	A x B	2.72	NS
CD 5%	8.00	B x A	3.29	NS

EY application showed significantly more P concentration than AY and TY applications.

The P concentration in straw showed the following decreasing trend : PM = SWS > SWC > FYM = CK.

4.1.5.3 Potassium

The trend of concentration in grains was : SWS > FYM > PM = SWC > CK. The EY application was on par with AY application, both being superior to TY application.

4.1.5.2 Iron

The trend of organic sources in respect of Fe concentration in grain was : PM > SWC = FYM = SWS > CK. In the interval of application the trend was : EY > AY > TY. The EY PM recorded significantly higher values than AY PM and TY PM. The EY PM and AY proved superior to their respective EY and AY application of the other organic sources.

The Fe concentration in straw showed following decreasing trend : PM = SWS = FYM = SWC > CK. In interval of application the trend was : EY > AY > TY. All the organic sources when applied every year proved better than their AY and TY applications.

4.1.5.5 Manganese

The effect of organic sources on Mn concentration in grain showed following decreasing trend : SWS > PM = SWS = FYM = CK.

Although application of organic sources resulted in higher Mn concentration in straw than control all organic sources were on par with each other. The interval of application showed the following decreasing trend : EY > AY > TY. The EY SWS did not differ significantly from EY PM both the treatments proved superior. The AY SWS did not differ with AY SWC, AY FYM and AY PM. The TY SWS was as good as AY FYM both were better than TY PM.

4.1.5.6 Zinc

The effect of organic sources on Zn concentration in grain showed following decreasing trend : SWS > SWC > PM > FYM > CK. In the interval of application trend was EY > AY > TY. The EY SWS found superior to AY SWS which also found superior to TY SWS. The EY SWS and AY SWS were much better than their respective other EY and AY application of other organic sources. The TY SWS was at par with TY PM and both found superior to other respective TY application of organic sources.

The effect of organic sources on Zn concentration in straw showed following decreasing trend : SWS > SWC > FYM > PM = CK and in interval of application, the trend was : EY > AY > TY. The EY SWS was found superior to AY SWS which was on par with TY SWS. All these three SWS applications proved significantly better than their respective application of organic sources.

4.1.5.7 Copper

The effect of interval of application on Cu concentration showed following decreasing order: EY > AY > TY.

Although organic sources resulted in higher Cu concentration in straw than control, the organic sources did not significantly differ from one another. The effect of interval of application showed the trend of EY > AY = TY.

Results showed that SWS application increased N, K, Zn in grain and straw and Mn in grain. The SWC ranked second in respect of N concentration in straw and grain, Zn in grain and straw. The PM increased P and Fe concentration in grain and straw, while, SWS ranked second in respect of P in grain which was, however, as good as SWC and FYM. The SWC ranked second in respect of Fe in grain.

By and large, the EY application increased concentration of all nutrients studied compared with AY application. The AY application was also superior to TY application. In general, EY SWS was superior to AY SWS in the majority of nutrients.

4.1.6 Residual effect of uptake of nutrients by wheat

Data on uptake of nutrients are presented in Table 10. The data on N, P and K uptake by grain is also presented in Fig. 3, 4 and 5. The effect of organic sources, interval of application and interaction on P uptake by grain was not significant. The interaction effect on N uptake by grain and total N uptake, P uptake by grain and straw, total P uptake, K uptake by grain, Fe uptake by straw. Mn uptake by grain, straw and total Mn uptake, Zn uptake by straw, Cu uptake by grain, straw was not significant.

4.1.6.1 Nitrogen uptake

The organic sources showed the following decreasing trend in respect of N uptake by grain : PM = SWC = SWS > FYM > CK. The trend in interval of application was : EY > AY > TY. All the EY organic sources proved better than their respective AY and TY applications.

Table 10. Residual effect of spent wash solids and spent wash - press mud compost and their interval of application on nutrient uptake by wheat grain, straw and total uptake

i) Nitrogen uptake by grain (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	101.60	134.30	134.60	131.30	127.60	125.82	0.47	1.39
AY	96.16	125.30	130.30	129.30	123.30	120.87		
TY	87.83	120.80	123.60	121.00	114.33	113.50		
Mean	95.19	126.80	129.00	127.00	121.74			

		Interaction	SEm ±	CD 5%
SEm ±	1.34	A x B	1.056	NS
CD 5%	4.38	B x A	1.59	NS

ii) Nitrogen uptake by straw (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	34.00	82.35	63.27	70.83	57.41	61.57	1.37	4.05
AY	34.27	65.78	56.65	59.67	46.97	52.66		
TY	37.82	50.03	43.20	49.71	44.66	45.00		
Mean	35.36	66.05	54.37	60.07	49.68			

		Interaction	SEm ±	CD 5%
SEm ±	2.06	A x B	3.07	9.05
CD 5%	6.72	B x A	3.24	9.78

iii) Total nitrogen uptake (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	135.6	216.6	197.8	202.1	185.0	187.4	3.18	9.38
AY	130.4	191.0	186.9	188.9	170.3	173.5		
TY	125.1	170.8	166.8	170.7	158.9	158.5		
Mean	130.40	192.8	183.8	187.3	160.4			

		Interaction	SEm ±	CD 5%
SEm ±	3.67	A x B	7.11	NS
CD 5%	11.97	B x A	6.87	NS

iv) Phosphorus uptake by grain (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	6.78	11.31	10.75	10.30	9.31	9.67	2.43	NS
AY	6.58	10.50	9.18	9.13	7.50	8.57		
TY	5.60	8.75	7.56	7.75	8.33	7.60		
Mean	6.31	10.18	9.16	9.00	8.34			

		Interaction	SEm ±	CD 5%
SEm ±	3.26	A x B	0.4	NS
CD 5%	NS	B x A	0.5	NS

v) Phosphorus uptake by straw (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	3.96	8.21	8.50	6.26	5.60	6.50	0.24	0.71
AY	4.02	5.84	7.18	5.17	4.32	5.30		
TY	4.61	5.45	6.46	4.87	4.32	5.14		
Mean	4.19	6.50	7.38	5.43	4.74			

		Interaction	SEm ±	CD 5%
SEm ±	0.32	A x B	0.54	NS
CD 5%	1.07	B x A	0.55	NS

vi) Total phosphorus uptake (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	10.74	19.51	19.20	16.50	14.81	16.15	0.34	1.00
AY	10.60	16.30	14.30	14.30	11.80	13.80		
TY	10.20	14.20	14.00	12.60	12.65	12.70		
Mean	10.50	14.60	16.50	14.30	13.30			

		Interaction	SEm ±	CD 5%
SEm ±	0.35	A x B	0.75	NS
CD 5%	1.17	B x A	0.71	NS

vii) Potassium uptake by grain (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	6.9	21.4	15.7	19.0	16.3	15.8	0.54	1.59
AY	7.5	20.5	14.8	14.8	13.7	14.2		
TY	8.8	16.2	12.7	15.4	15.7	13.8		
Mean	7.7	19.3	14.4	16.4	15.2			

		Interaction	SEm ±	CD 5%
SEm ±	0.93	A x B	1.2	NS
CD 5%	3.04	B x A	1.3	NS

viii) Potassium uptake by straw (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	106	191	143	162	150	151	2.70	7.90
AY	107	168	145	126	126	134		
TY	106	141	136	122	118	125		
Mean	106	167	141	135	132			

		Interaction	SEm ±	CD 5%
SEm ±	4.5	A x B	6.02	17.77
CD 5%	14.7	B x A	6.69	20.27

ix) Total potassium uptake (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	113	212	158	155	166	160	3.00	9.00
AY	114	188	159	140	139	148		
TY	114	157	148	137	133	137		
Mean	114	185	155	144	146			

		Interaction	SEm ±	CD 5%
SEm ±	5.0	A x B	6.6	19.67
CD 5%	16.0	B x A	7.3	22.07

x) Iron uptake by grain (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	1.00	1.43	1.82	1.42	1.25	1.38	0.036	0.10
AY	0.99	1.31	1.30	1.16	1.00	1.15		
TY	0.94	1.06	0.91	0.97	1.12	1.00		
Mean	0.97	1.26	1.34	1.18	1.12			

		Interaction	SEm ±	CD 5%
SEm ±	0.03	A x B	0.08	0.23
CD 5%	0.11	B x A	0.07	0.22

xi) Iron uptake by straw (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	1.11	1.64	2.18	1.59	1.59	1.62	0.057	0.16
AY	1.07	1.22	1.40	1.15	1.23	1.21		
TY	1.02	1.36	1.39	1.18	1.30	1.25		
Mean	1.06	1.40	1.65	1.30	1.37			

		Interaction	SEm ±	CD 5%
SEm ±	0.05	A x B	0.12	NS
CD 5%	0.18	B x A	0.12	NS

xii) Total iron uptake (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	2.11	3.07	4.00	3.01	2.87	3.01	0.071	0.21
AY	2.06	2.53	2.70	2.30	2.20	2.35		
TY	1.96	2.42	2.30	2.15	2.37	2.24		
Mean	2.04	2.67	3.00	2.48	2.48			

		Interaction	SEm ±	CD 5%
SEm ±	0.09	A x B	0.15	0.46
CD 5%	0.30	B x A	0.16	0.48

xiii) Manganese uptake by grain (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.21	0.29	0.29	0.25	0.24	0.25	0.008	0.025
AY	0.20	0.28	0.23	0.21	0.18	0.22		
TY	0.19	0.22	0.18	0.18	0.21	0.19		
Mean	0.20	0.26	0.23	0.21	0.21			

			Interaction	SEm ±	CD 5%
SEm ±	0.01		A x B	0.02	NS
CD 5%	0.03		B x A	0.02	NS

xiv) Manganese uptake by straw (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.18	0.37	0.42	0.34	0.34	0.33	0.01	0.03
AY	0.16	0.28	0.25	0.24	0.24	0.23		
TY	0.17	0.26	0.25	0.25	0.29	0.24		
Mean	0.17	0.30	0.30	0.27	0.29			

			Interaction	SEm ±	CD 5%
SEm ±	0.015		A x B	0.027	NS
CD 5%	0.050		B x A	0.027	NS

xv) Total manganese uptake (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.39	0.66	0.71	0.59	0.58	0.58	0.01	0.04
AY	0.36	0.56	0.48	0.45	0.42	0.45		
TY	0.36	0.48	0.43	0.43	0.50	0.44		
Mean	0.37	0.56	0.54	0.49	0.50			

			Interaction	SEm ±	CD 5%
SEm ±	0.03		A x B	0.03	NS
CD 5%	0.10		B x A	0.04	NS

xvi) Zinc uptake by grain (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.19	0.75	0.43	0.53	0.40	0.46	0.015	0.044
AY	0.20	0.52	0.32	0.41	0.27	0.34		
TY	0.19	0.31	0.23	0.21	0.22	0.23		
Mean	0.19	0.52	0.32	0.38	0.29			

		Interaction	SEm ±	CD 5%
SEm ±	0.01	A x B	0.03	0.01
CD 5%	0.05	B x A	0.03	0.09

xvii) Zinc uptake by straw (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.47	1.15	0.61	0.89	0.87	0.79	0.03	0.09
AY	0.40	0.86	0.39	0.65	0.53	0.56		
TY	0.44	0.77	0.40	0.61	0.54	0.55		
Mean	0.43	0.92	0.46	0.71	0.64			

		Interaction	SEm ±	CD 5%
SEm ±	0.04	A x B	0.06	NS
CD 5%	0.14	B x A	0.07	NS

xviii) Total zinc uptake (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.66	1.90	1.04	1.42	1.27	1.25	0.03	0.10
AY	0.60	1.56	0.71	1.06	0.94	0.97		
TY	0.63	1.08	0.63	0.82	0.76	0.78		
Mean	0.63	1.51	0.79	1.10	0.99			

		Interaction	SEm ±	CD 5%
SEm ±	0.05	A x B	0.07	0.22
CD 5%	0.16	B x A	0.08	0.24

xix) Copper uptake by grain (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.21	0.29	0.29	0.25	0.24	0.25	0.008	0.024
AY	0.20	0.28	0.23	0.21	0.18	0.22		
TY	0.18	0.22	0.18	0.18	0.21	0.19		
Mean	0.20	0.26	0.23	0.21	0.21			

			Interaction	SEm ±	CD 5%
SEm ±	0.01		A x B	0.02	NS
CD 5%	0.03		B x A	0.02	NS

xx) Copper uptake by straw (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.13	0.22	0.22	0.20	0.23	0.20	0.008	0.024
AY	0.13	0.19	0.16	0.13	0.16	0.15		
TY	0.14	0.16	0.13	0.14	0.18	0.15		
Mean	0.13	0.19	0.17	0.15	0.19			

			Interaction	SEm ±	CD 5%
SEm ±	0.01		A x B	0.02	NS
CD 5%	0.04		B x A	0.02	NS

xxi) Total copper uptake (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.34	0.48	0.51	0.45	0.47	0.45	0.01	0.03
AY	0.33	0.47	0.39	0.34	0.34	0.37		
TY	0.33	0.38	0.31	0.32	0.39	0.34		
Mean	0.33	0.44	0.40	0.37	0.40			

			Interaction	SEm ±	CD 5%
SEm ±	0.02		A x B	0.03	0.08
CD 5%	0.06		B x A	0.03	0.09

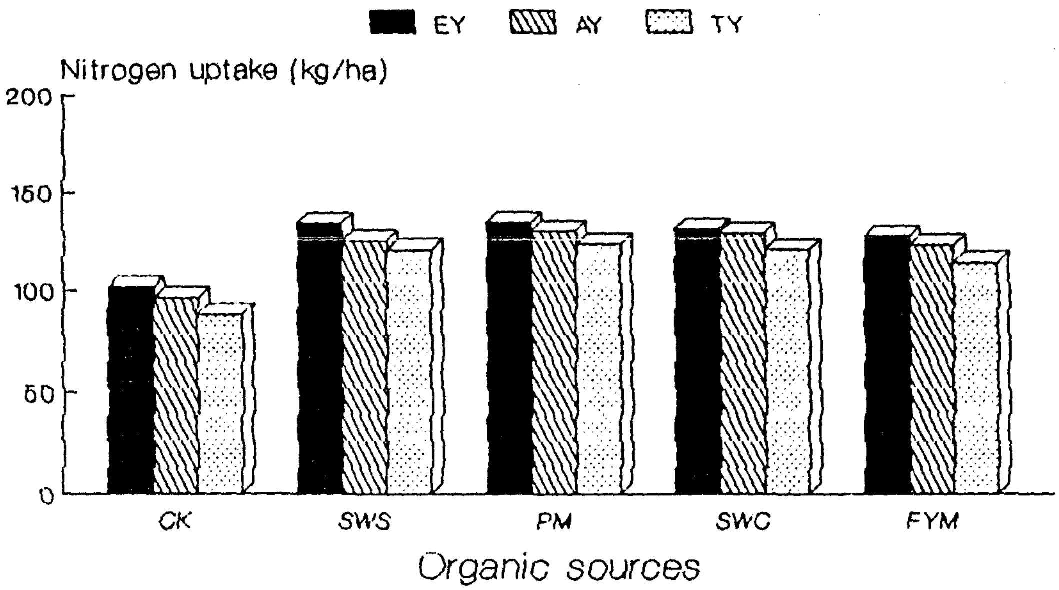


Fig.3. Residual effect of SWS, SWC and their interval of application on N uptake by wheat grain

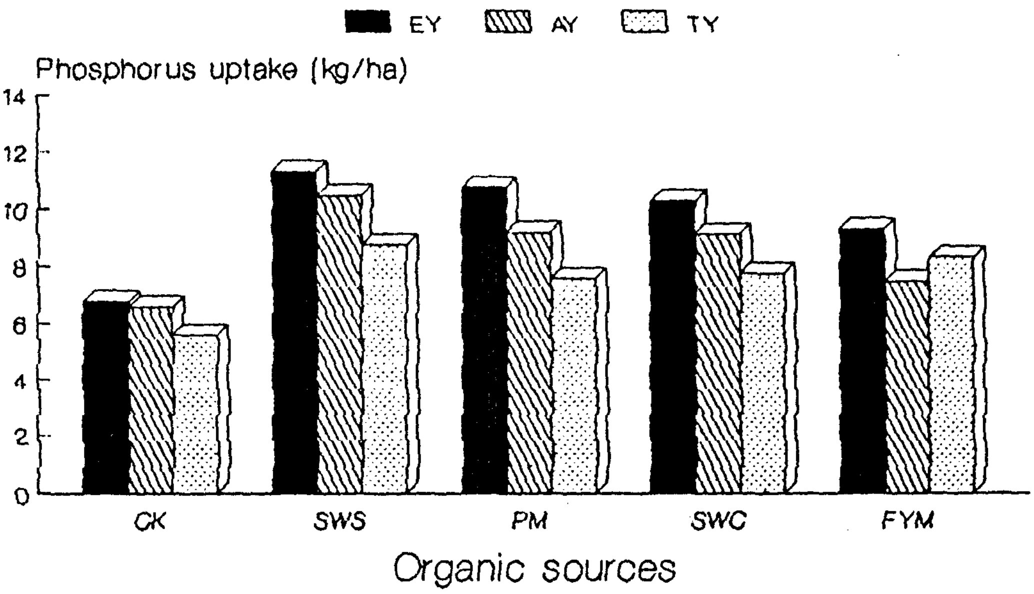


Fig.4. Residual effect of SWS, SWC and their interval of application on P uptake by wheat grain

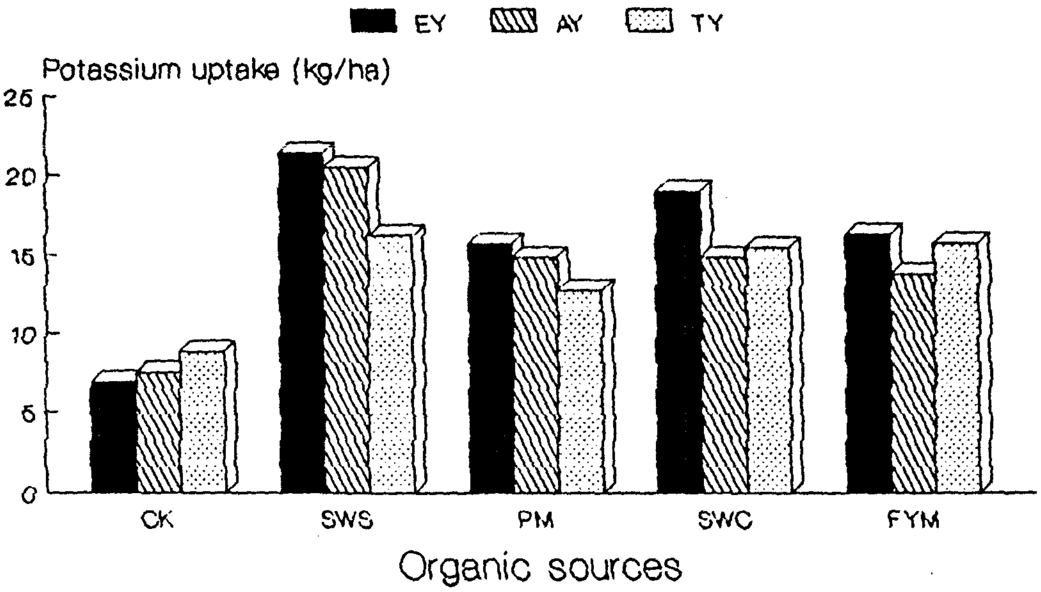


Fig.5. Residual effect of SWS, SWC and their interval of application on K uptake by wheat grain

The SWS recorded the highest N uptake by straw. It was, however, at par with SWC and proved better than PM and FYM. The trend in interval of application was : EY > AY > TY. The EY SWS and AY SWS recorded higher values than their respective EY and AY application of other organic sources.

The total nitrogen uptake showed following decreasing trend : SWS = SWC = PM > FYM > CK. In interval of application trend was : EY > AY > TY.

4.1.6.2 Phosphorus uptake

The P uptake in straw was the highest in PM (7.38 kg ha^{-1}) which was, however, at par with SWS. The SWS was on par with SWC. The FYM was as good as control. The interval of application showed following trend : EY > AY > TY.

Total uptake of P showed the following trend : SWS = PM > SWC > FYM > CK. In interval of application the trend was : EY > AY > TY.

4.1.6.3 Potassium uptake

The SWS recorded the highest K uptake by grain which was, however, on par with SWC and proved better than FYM and PM uptake by grain. In interval of application the trend was : EY > AY = TY.

The uptake by straw showed the following decreasing trend : SWS > PM = SWC = FYM > CK. In interval of application the trend was EY > AY > TY. The EY SWS and AY SWS showed the higher values than their respective EY and AY applications of other sources.

Total K uptake showed the following trend : SWS > PM = FYM = SWC > CK. In interval of application the trend was : EY > AY > TY.

4.1.6.4 Iron uptake

The iron uptake in grain showed following decreasing trend PM > SWS > SWC = FYM > CK. In interval of application the trend was : EY > AT > TY. The EY PM showed the highest value which was significantly higher than all other individual organic sources.

The Fe uptake in straw was the highest in PM which was significantly greater than SWS and other organic sources. In interval of application the trend was : EY > TY > = AY.

The total Fe uptake was observed in following decreasing order : PM > SWS = SWC = FYM > CK. The trend in interval of application was : EY > AY = TY. The EY PM and AY PM proved better than other respective EY and AY applications.

4.1.6.5 Manganese uptake

The Mn uptake by grain was the highest in SWS which was on par with PM and significantly better than SWC and FYM in interval of application the trend was : EY > AY > TY.

The application of organic sources resulted in higher Mn uptake by straw than CK. The sources were on par with each other. The interval of application showed the trend of EY > AY = TY.

The total Mn uptake showed the following decreasing trend SWS = PM = FYM = SWC > CK. The trend in interval of application was : EY > AY = TY.

4.1.6.6 Zinc uptake

The Zn uptake in grain was in following decreasing order : SWS > SWC > PM = FYM > CK. The trend in interval of application was EY > AY > TY. The EY SWS proved better than all other applications of organic sources.

The trend in Zn uptake in straw and total Zn uptake was similar as described in Zn uptake in grain except interaction effect in Zn uptake by straw was not significant.

4.1.6.7 Copper uptake

The SWS, PM were at par in respect of Cu uptake in grain and only SWS proved better than other sources and the other sources being on par with CK. The EY application proved better than AY and TY applications.

Similar trend was observed in Cu uptake of straw as that of Cu uptake by grain in respect of organic sources. The following trend was observed in Cu uptake by straw in interval of application : EY > AY = TY.

Although organic sources resulted in higher total Cu uptake than control, the sources were at par with each other. The trend in interval of application was : EY > AY > TY. The EY PM and AY PM showed the higher values than the other EY and AY respective applications.

Results obtained showed that SWS, SWC and PM had equal residual effect on N uptake and all these three sources showed better residual effect than FYM. The P and Cu uptake was similar in SWS and PM and these two sources increased total P uptake compared with SWC and FYM. For K and Zn uptake of SWS proved better than Pm and SWC including FYM. The residual effect of organic sources was more or less similar.

The EY application of organic sources was found superior in respect of uptake of all nutrients. While the AY applicaiton ranked second. This was because in EY application treatment there were six applications of organic sources, while in AY application there were only three applications of organic soiurces. More number of times applications benefited the soil to the greater extent than less number of applications.

During first year of the experimentation, increased uptake of N, P, Fe, Zn, Mn and Cu was observed in all the organic sources, while SWS increased uptake of K by wheat compared with other sources (Shinde et al., 1993b). During second year, the SWC increased N uptake by wheat grain and sources showed similar effect on uptake of other nutrients (Shinde et al., 1995a). The SWC increased N, K, Mn and Zn uptake by third year wheat and all sources showed similar effect on P uptake, while the EY application proved better for N, K, Fe, Mn and Zn uptake (Shinde et al., 1995c). During fourth year, the higher N and K uptake was found in SWS treatment, while SWS and SWC found inferior to PM in respect of P uptake. The SWS was found better in respect of Mn and Zn uptake, the SWC ranked second in Zn uptake, while SWS and SWC showed lower effect on Fe uptake. The EY SWS was found better than its AY and TY application during fourth year of the experiment (Ove, 1995). During fifth year SWS had residual effect on N, K, Mn, Zn and Cu uptake. The SWC ranked second in respect of N, Zn, Mn uptake. The EY SWS proved better in respect of all nutrient uptake (Gawande, 1996).

4.1.7 Residual effect on proximate composition of wheat grain

Data obtained on crude protein, crude fibre and crude fat content of grain are presented in Table 11. The data on crude protein in grain is also presented in Fig. 6. Effect of organic sources, interval of application on crude fat was not significant and effect of interval of application on crude fibre content was not significant. Similarly, effect of interaction on crude fibre content was not significant.

4.1.7.1 Crude protein

Application of organic sources resulted in higher crude protein content than control. The highest crude protein was observed in SWS treatment which was significantly superior to all other organic sources. It might be because of higher N fertility status before sowing of wheat. The PM and FYM were on par with each other. The trend in interval of application was : EY > AY > TY.

Table 11. Residual effect of spent wash solids and spent wash - press mud compost and their interval of application on crude protein, crude fibre and crude fat content

i) Crude protein (%)

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	11.93	19.31	15.96	13.73	15.68	15.32	0.16	0.50
AY	12.26	16.20	13.70	12.21	13.90	13.65		
TY	12.49	15.06	12.58	11.39	12.36	12.36		
Mean	12.22	16.85	14.00	14.08	13.98			

		Interaction	SEm ±	CD 5%
SEm ±	0.26	A x B	0.37	1.10
CD 5%	0.87	B x A	0.41	1.20

ii) Crude fibre (%)

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	1.71	1.75	1.73	1.73	1.74	1.73	0.003	NS
AY	1.71	1.74	1.74	1.75	1.73	1.73		
TY	1.70	1.74	1.74	1.74	1.73	1.73		
Mean	1.70	1.74	1.73	1.74	1.73			

		Interaction	SEm ±	CD 5%
SEm ±	0.002	A x B	0.006	NS
CD 5%	0.001	B x A	0.006	NS

iii) Crude fat (%)

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.45	0.51	0.50	0.50	0.49	0.49	0.008	NS
AY	0.47	0.50	0.49	0.47	0.49	0.48		
TY	0.45	0.49	0.46	0.47	0.46	0.47		
Mean	0.45	0.50	0.48	0.48	0.48			

		Interaction	SEm ±	CD 5%
SEm ±	0.009	A x B	0.018	NS
CD 5%	NS	B x A	0.017	NS

iv) Soluble carbohydrate (%)

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	72.7	65.6	68.7	71.7	69.4	69.6	0.25	0.73
AY	72.8	70.6	71.9	73.4	72.2	72.2		
TY	72.5	69.8	72.3	73.9	73.1	72.3		
Mean	72.6	68.6	71.0	73.0	71.6			

		Interaction	SEm ±	CD 5%
SEm ±	0.22	A x B	0.56	1.65
CD 5%	0.72	B x A	0.50	1.51

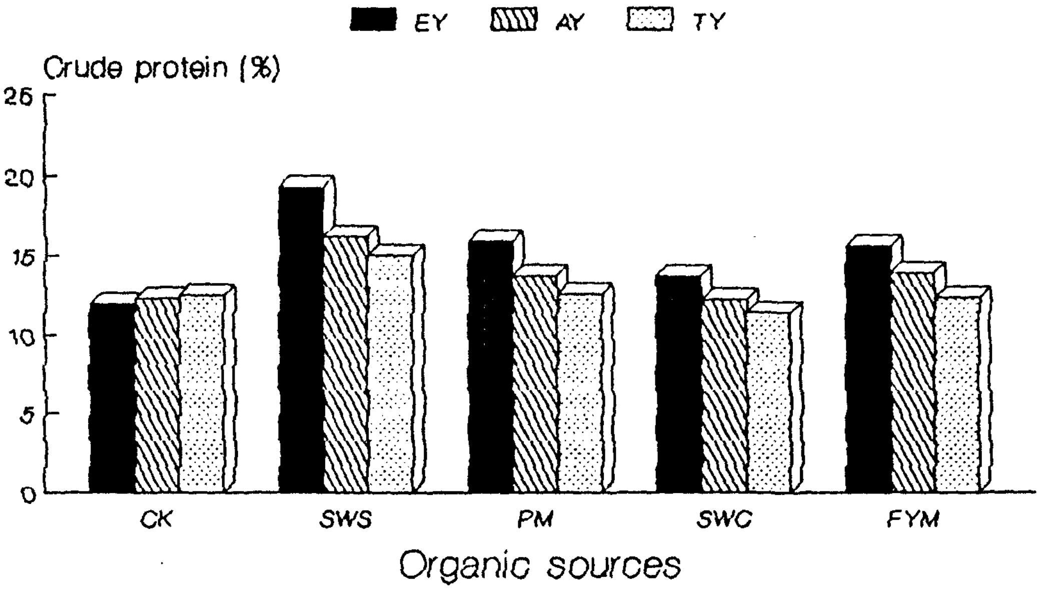


Fig.6. Residual effect of SWS, SWC and their interval of application on crude protein of wheat grain

The EY SWS was found superior to its AY and TY applications and all these three SWS applications resulted in significantly higher crude protein content than their respective EY, AY and TY application of other organic sources.

4.1.7.2 Crude fibre

Although all organic sources recorded higher crude fibre content than control, the sources were at par with each other.

4.1.7.3 Soluble carbohydrate

The lowest soluble carbohydrate content was found in SWS treatment indicating conversion of soluble carbohydrates into crude protein as increase amount of crude protein was observed in this treatment. Higher soluble carbohydrates were observed in SWC and CK treatments. The FYM and PM treatments were at par.

Results obtained showed that the SWS increased crude protein content and decreased soluble carbohydrate content compared with other organic sources. The organic sources increased crude fibre content compared with control. The crude protein increased by EY application of organic sources. The EY application of SWS increased crude protein content. Which was also observed by (Gawande, 1996). Belhekar (1995) also obtained higher crude protein content in sorghum fodder with SWS application.

4.1.8 Residual effect on chemical properties of soil after harvest of wheat

The data on chemical properties are presented in Table 12. The data on available N, P and K in soil is also presented in Fig. 7, 8 and 9. The effect of organic sources, interval of application and interaction on pH, EC, available N, available Mn was not significant. The effect of interval of application and interaction effect on organic carbon, available K, Fe and Cu was not significant. So also the interaction effect on available P, Zn, Ni, Co, Cd and Cr.

4.1.8.1 Organic carbon

The highest organic carbon was found in SWS treatment which was at par with SWC and PM and was found superior to FYM.

4.1.8.2 Available phosphorus

Application of organic sources resulted in higher available P in soil compared with control. The sources were

Table 12. Residual effect of spent wash solids and spent wash-press mud compost and their interval of application on fertility of soil after harvest of wheat

i) pH

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	8.53	8.50	8.53	8.46	8.56	8.51	0.017	NS
AY	8.46	8.50	8.50	8.56	8.53	8.52		
TY	8.50	8.56	8.50	8.50	8.53	8.52		
Mean	8.49	8.52	8.51	8.50	8.54			

		Interaction	SEm ±	CD 5%
SEm ±	0.02	A x B	0.04	NS
CD 5%	NS	B x A	0.03	NS

ii) Electrical conductivity (dS m^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.135	0.162	0.155	0.180	0.147	0.155	0.003	NS
AY	0.138	0.152	0.148	0.161	0.153	0.150		
TY	0.139	0.149	0.167	0.150	0.137	0.148		
Mean	0.137	0.154	0.156	0.63	0.145			

		Interaction	SEm ±	CD 5%
SEm ±	0.006	A x B	0.007	NS
CD 5%	NS	B x A	0.008	NS

iii) Organic carbon (%)

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.18	0.80	0.70	0.80	0.70	0.63	0.04	NS
AY	0.24	0.92	0.80	0.80	0.50	0.65		
TY	0.26	1.00	0.66	0.68	0.60	0.64		
Mean	0.22	0.90	0.72	0.76	0.60			

		Interaction	SEm ±	CD 5%
SEm ±	0.07	A x B	0.08	NS
CD 5%	0.21	B x A	0.10	NS

iv) Available nitrogen (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	193	209	207	210	214	207	7.05	NS
AY	195	204	205	210	209	205		
TY	191	203	201	206	206	201		
Mean	193	206	204	209	209			

		Interaction	SEm ±	CD 5%
SEm ±	9.1	A x B	15.7	NS
CD 5%	NS	B x A	16.3	NS

v) Available phosphorus (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	17.50	21.60	21.00	20.70	20.60	20.30	0.40	1.30
AY	16.50	19.30	19.70	18.60	11.70	18.50		
TY	16.10	19.00	15.00	16.60	17.60	16.90		
Mean	16.70	19.90	18.50	18.70	19.00			

		Interaction	SEm ±	CD 5%
SEm ±	0.5	A x B	0.9	NS
CD 5%	1.5	B x A	0.9	NS

vi) Available potassium (kg ha^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	343	634	551	433	597	515	10	NS
AY	354	608	530	425	582	500		
TY	343	597	504	418	578	488		
Mean	347	613	535	425	586			

		Interaction	SEm ±	CD 5%
SEm ±	20	A x B	22	NS
CD 5%	66	B x A	27	NS

vii) Available iron (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	5.8	10.3	9.3	8.1	9.5	8.6	0.17	NS
AY	6.3	9.9	8.4	8.1	8.4	8.2		
TY	5.7	9.6	8.4	8.4	8.0	8.0		
Mean	5.9	9.9	8.7	8.2	8.7			

		Interaction	SEm ±	CD 5%
SEm ±	0.7	A x B	0.4	NS
CD 5%	2.3	B x A	0.7	NS

viii) Available manganese (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	8.6	11.2	12.6	9.7	11.0	10.6	0.31	NS
AY	7.8	10.7	11.4	9.6	10.3	9.9		
TY	8.2	11.1	10.9	9.8	10.1	10.0		
Mean	8.2	11.0	11.6	9.7	10.5			

		Interaction	SEm ±	CD 5%
SEm ±	1.0	A x B	0.7	NS
CD 5%	NS	B x A	1.2	NS

xi) Available zinc (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.45	0.89	0.72	0.68	0.75	0.72	0.03	0.09
AY	0.29	0.73	0.73	0.71	0.67	0.62		
TY	0.24	0.68	0.63	0.58	0.51	0.52		
Mean	0.32	0.76	0.69	0.69	0.64			

		Interaction	SEm ±	CD 5%
SEm ±	0.05	A x B	0.07	NS
CD 5%	0.16	B x A	0.07	NS

x) Available copper (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	1.44	2.11	2.22	2.42	2.24	2.08	0.07	NS
AY	1.63	2.39	2.20	1.91	2.18	2.02		
TY	1.26	1.96	1.99	2.34	2.33	1.97		
Mean	1.37	2.15	2.13	2.22	2.25			

			Interaction	SEm ±	CD 5%
	SEm ±	0.16	A x B	0.17	NS
	CD 5%	0.52	B x A	0.21	NS

xi) Available Nickel (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.18	0.32	0.28	0.28	0.26	0.26	0.003	0.08
AY	0.18	0.30	0.26	0.27	0.25	0.25		
TY	0.19	0.28	0.25	0.26	0.24	0.24		
Mean	0.18	0.30	0.26	0.27	0.25	0.25		

			Interaction	SEm ±	CD 5%
	SEm ±	0.004	A x B	0.006	NS
	CD 5%	0.013	B x A	0.006	NS

xii) Available Cobalt (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.52	0.74	0.65	0.69	0.61	0.64	0.005	0.014
AY	0.50	0.72	0.62	0.66	0.63	0.62		
TY	0.52	0.69	0.61	0.65	0.57	0.60		
Mean	0.51	0.72	0.62	0.66	0.60			

			Interaction	SEm ±	CD 5%
	SEm ±	0.01	A x B	0.01	NS
	CD 5%	0.05	B x A	0.02	NS

xiii) Available Cadmium (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.026	0.073	0.043	0.047	0.037	0.045	0.001	0.004
AY	0.023	0.060	0.030	0.033	0.023	0.034		
TY	0.023	0.053	0.023	0.033	0.020	0.031		
Mean	0.023	0.062	0.32	0.038	0.027	0.036		

		Interaction	SEm ±	CD 5%
SEm ±	0.002	A x B	0.003	NS
CD 5%	0.005	B x A	0.003	NS

xiv) Available Cromium (mg kg^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.12	0.25	0.21	0.22	0.18	0.19	0.003	0.008
AY	0.12	0.23	0.20	0.20	0.16	0.18		
TY	0.12	0.21	0.17	0.19	0.15	0.17		
Mean	0.12	0.23	0.20	0.20	0.17	0.18		

		Interaction	SEm ±	CD 5%
SEm ±	0.005	A x B	0.006	NS
CD 5%	0.017	B x A	0.007	NS

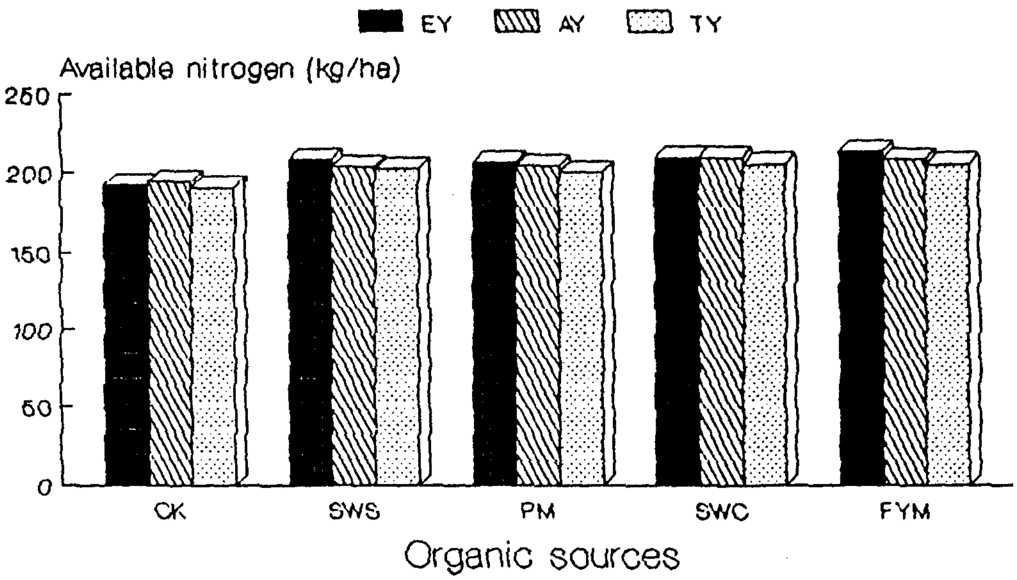


Fig.7. Residual effect of SWS, SWC and their interval of application on N of soil after harvest of wheat

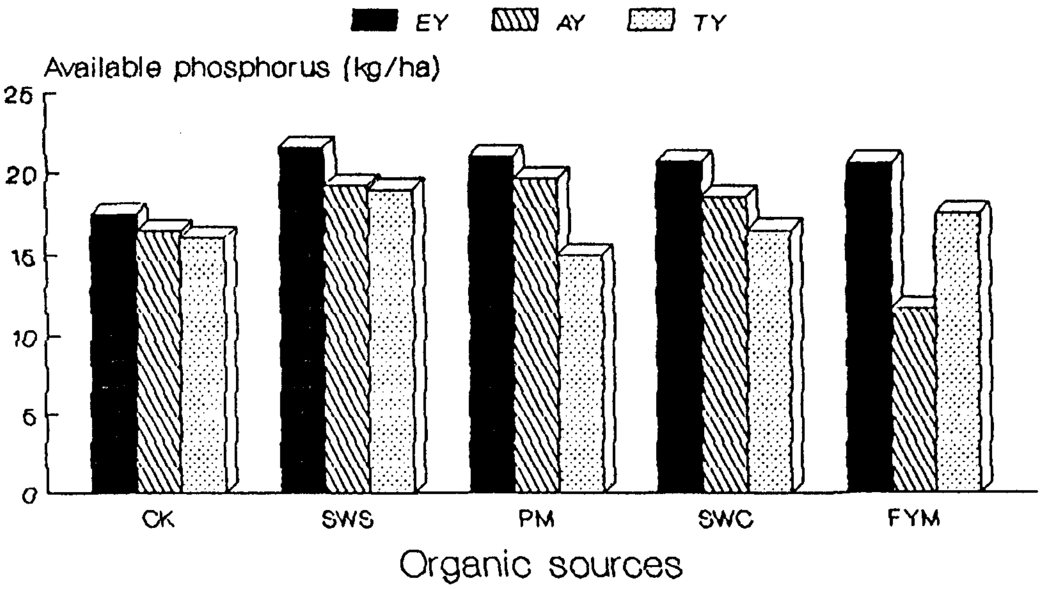


Fig.8. Residual effect of SWS, SWC and their interval of application on P of soil after harvest of wheat

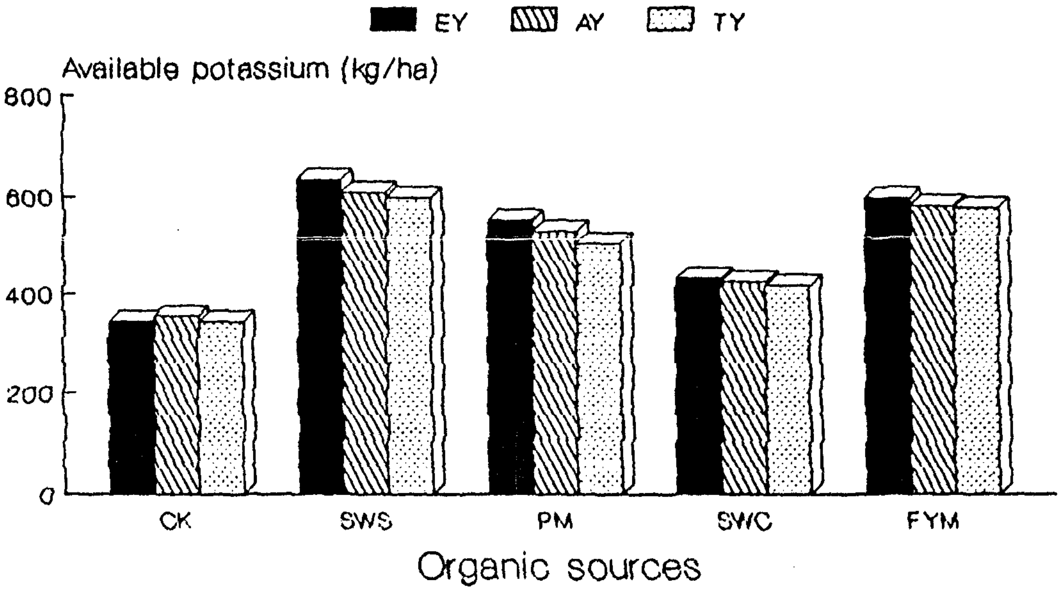


Fig.9. Residual effect of SWS, SWC and their interval of application on K^+ of soil after harvest of wheat

however, on par with each other. The EY application showed higher available P than AY SWS and TY applications the former being better than the latter.

4.1.8.3 Available potassium

The effect of organic sources on the available K in soil showed the following decreasing trend : SWS = FYM = PM > SWC > CK.

4.1.8.4 Available iron

Although organic sources showed significantly higher values than control, they were at par with each other.

4.1.8.5 Available Zn

The organic sources showed the following decreasing trend : SWS > PM = SWC = FYM > CK. In interval of application the trend was : EY > AY > TY.

4.1.8.6 Available copper

Application of organic sources resulted in increased available Cu. However, the sources were at par with each other.

4.1.8.7 Available nickel

The organic sources showed the following decreasing trend of available Ni in soil : SWS > SWC = PM > FYM > CK. In interval of application the trend was : EY > AY > TY.

4.1.8.8 Available cobalt

The organic source showed the following decreasing trend in available Co in soil : SWS > SWC = PM = FYM = CK. In interval of application the trend was : EY > AY > TY.

4.1.8.9 Available cadmium

In organic sources, the SWS recorded the highest value of Cd (0.062 mg kg^{-1}) and was significantly superior to all treatments followed by SWC, PM and FYM. In interval of application the trend was : EY > AY > TY.

4.1.8.10 Available chromium

The organic sources showed the following decreasing trend in available chromium in soil : SWS > SWC > PM > FYM CK. In interval of application the trend was : EY > AY > TY.

Results obtained showed that SWS and SWC had equal effect on organic carbon content of soil. The SWC was found better than FYM in this respect. Organic sources showed similar residual effect on available P, Fe and Cu content of soil. The SWS, FYM and PM had similar effect on available K content of soil. The SWS increased Ni, Cd and Cr content of soil, while the SWC ranked second in this respect. The SWS application increased available Zn content of soil followed by SWC. Use of SWS and SWC for long period of time in crop production might increase the heavy metal content of soil. This has also reflected in the EY application of organic sources as the higher content of these heavy metals were observed in soil than Ay and Ty applications.

During first year of the experiment all sources increased available N, K, Fe, Mn content of soil and SWC, PM and FYM increased organic carbon and available P content after harvest of wheat (Shinde et al., 1993c). The SWC and SWS showed build up of available N and K in soil after harvest of second year wheat (Shinde et al., 1995a). During third year of experimentation higher build up of available N and P in soil by SWC application was noted, while, it was SWS for organic carbon, available K, Mn and Zn build up in soil. The SWS and SWC showed equal effect on available Fe and proved superior to other sources (Shinde et al., 1995c). During fourth year, the

SWS and SWC showed build up of available N and K in soil after harvest of wheat. The SWS also increased available Zn and Cu content in soil (Ove, 1995) during fourth year after harvest of wheat. During fifth year SWC and SWS increased EC of soil. SWS helped to build up organic carbon, available P and K of soil. The SWS and SWC were comparable in building available Mn (Gawande, 1996).

4.1.9 Residual effect on composition of saturation paste extract (SPE) of soil after harvest of wheat

Data on composition of SPE of soil are presented in Table 13. The data on EC, k^+, HCO_{-3} and SO_{-4} are also presented in Fig. 10, 11, 12 and 13. The effect of organic sources, interval of application and interaction on pH was not significant. Similarly, effect of interaction on Na^+, Cl^- and SO_4^{2-} was not significant.

4.1.9.1 Electrical conductivity

Application of organic sources increased the EC of SPE. The highest increase in EC of SPE was observed in SWS which was significantly higher than all other organic sources (Fig. 10). However, the value of 0.69 dS m^{-1} is much below the critical level of 4 ds m^{-1} of SPE of soil. The EC value of

Table 13. Residual effect of spent wash solids and spent wash - press mud compost and their interval of application on composition of saturation paste extract of soil after harvest of wheat

i) pH

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	8.2	8.1	8.2	8.2	8.2	8.2	0.13	NS
AY	8.2	8.2	8.2	8.2	8.2	8.2		
TY	8.1	8.2	8.2	8.2	8.1	8.1		
Mean	8.1	8.1	8.2	8.2	8.1			

			Interaction	SEm ±	CD 5%
	SEm ±	0.01	A x B	0.03	NS
	CD 5%	NS	B x A	0.03	NS

ii) Electrical conductivity (dS m^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.50	0.88	0.66	0.63	0.67	0.67	0.016	0.048
AY	0.44	0.51	0.58	0.60	0.56	0.54		
TY	0.42	0.68	0.48	0.51	0.49	0.51		
Mean	0.45	0.69	0.57	0.58	0.57			

			Interaction	SEm ±	CD 5%
	SEm ±	0.02	A x B	0.03	0.10
	CD 5%	0.08	B x A	0.04	0.11

iii) Potassium (me L^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.049	0.114	0.098	0.103	0.103	0.093	0.002	0.005
AY	0.043	0.097	0.070	0.070	0.075	0.071		
TY	0.041	0.078	0.067	0.073	0.063	0.064		
Mean	0.044	0.096	0.078	0.082	0.080			

			Interaction	SEm ±	CD 5%
	SEm ±	0.003	A x B	0.004	0.011
	CD 5%	0.008	B x A	0.004	0.012

iv) Sodium (me L^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	1.8	2.4	2.2	2.2	2.4	2.2	0.014	0.041
AY	1.6	2.2	2.1	2.0	2.1	2.0		
TY	1.5	2.0	2.1	2.0	2.0	1.9		
Mean	1.6	2.2	2.1	2.1	2.0			

		Interaction	SEm ±	CD 5%
SEm ±	0.02	A x B	0.03	NS
CD 5%	0.07	B x A	0.03	NS

v) Calcium + Magnsium (me L^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	3.0	6.9	4.2	4.7	4.6	4.7	0.07	0.22
AY	2.9	4.3	3.7	3.9	3.3	3.6		
TY	2.5	4.0	3.4	3.5	2.8	3.3		
Mean	2.8	5.0	3.8	4.0	3.6			

		Interaction	SEm ±	CD 5%
SEm ±	0.10	A x B	0.17	0.50
CD 5%	0.32	B x A	0.17	0.51

vi) Bicarbonates (me L^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	1.04	4.14	3.26	3.26	3.30	3.00	0.12	0.35
AY	2.42	3.10	2.36	2.56	2.60	2.60		
TY	2.25	2.42	2.40	2.40	2.20	2.30		
Mean	1.90	3.20	2.70	2.74	2.70			

		Interaction	SEm ±	CD 5%
SEm ±	0.14	A x B	0.27	0.79
CD 5%	0.48	B x A	0.26	0.79

vii) Sulphates (me L^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	1.8	3.6	2.0	2.5	2.3	2.4	0.04	0.14
AY	1.8	3.4	1.8	2.4	1.8	2.2		
TY	1.7	3.3	1.8	1.9	1.2	2.1		
Mean	1.8	3.4	1.9	2.3	2.0			

			Interaction	SEm ±	CD 5%
	SEm ±	0.07	A x B	0.10	NS
	CD 5%	0.23	B x A	0.11	NS

viii) Chlorides (me L^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	1.90	3.50	2.70	2.50	3.20	2.76	0.08	0.25
AY	1.26	3.20	2.20	1.90	2.20	2.15		
TY	1.10	2.20	2.00	2.00	2.06	1.87		
Mean	1.40	2.96	2.30	2.10	2.50			

			Interaction	SEm ±	CD 5%
	SEm ±	0.13	A x B	0.19	NS
	CD 5%	0.43	B x A	0.20	NS

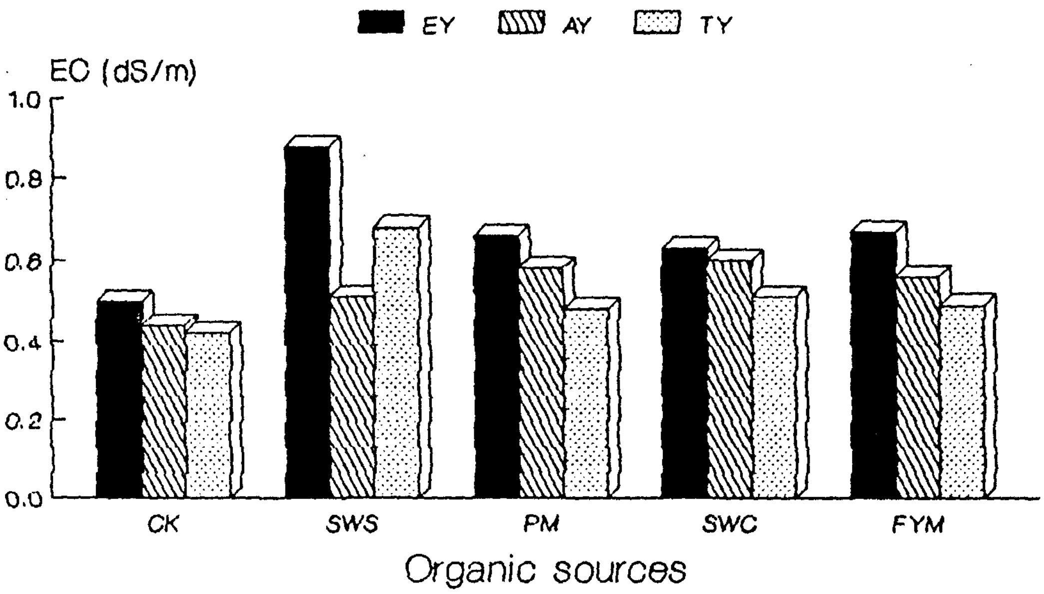


Fig.10. Residual effect of SWS, SWC and their interval of application on EC of SPE of soil after harvest of wheat

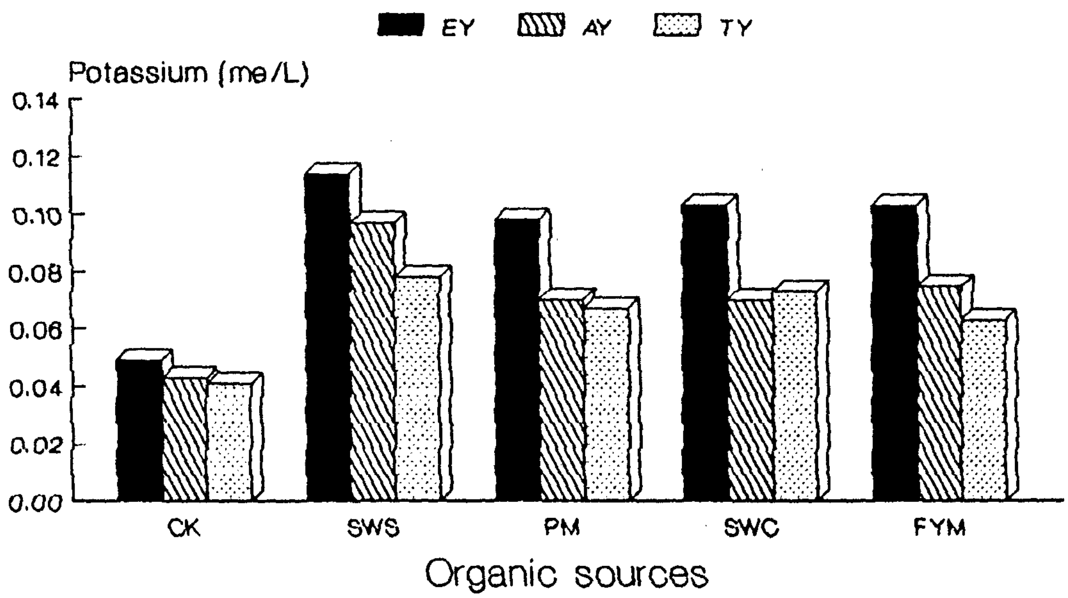


Fig.11. Residual effect of SWS, SWC and their interval of application on K+ of SPE of soil after harvest of wheat

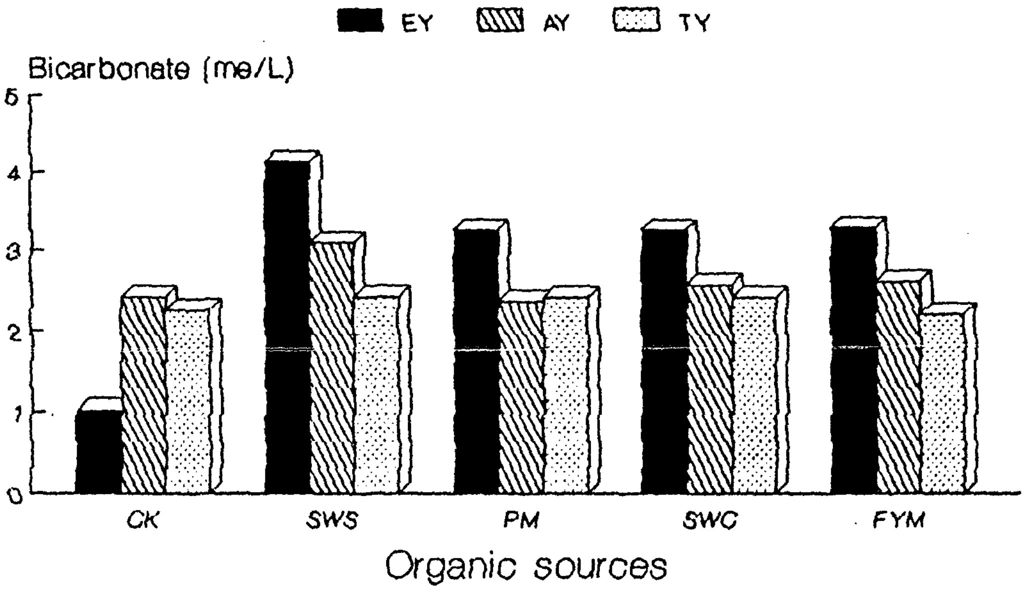


Fig.12. Residual effect of SWS, SWC and their interval of application on HCO_3^- of SPE of soil after harvest of wheat

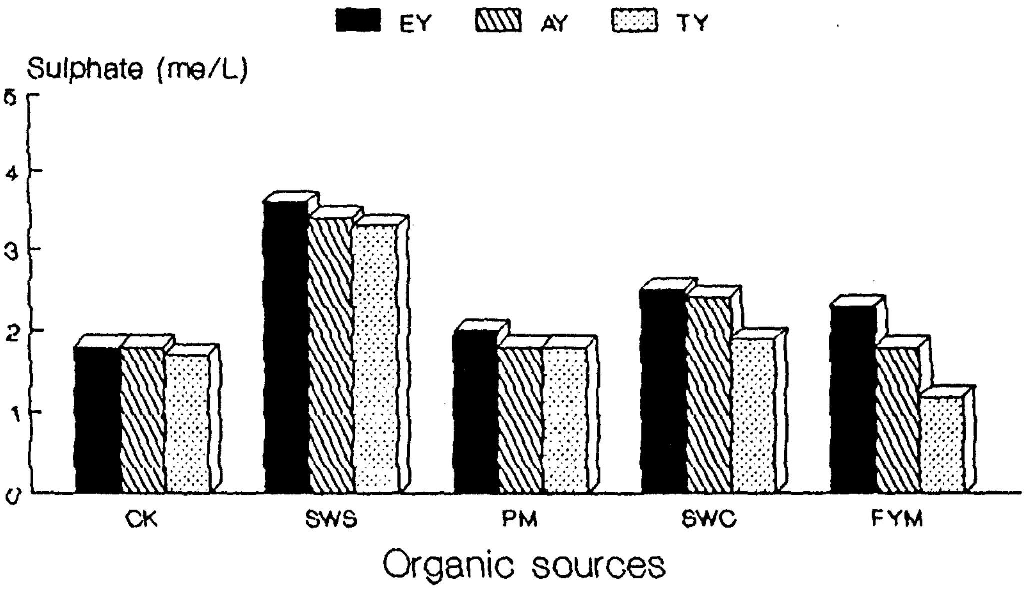


Fig.13. Residual effect of SWS, SWC and their interval of application on SO_4^{2-} of SPE of soil after harvest of wheat

FYM, PM and SWC was comparable which was however, higher than control. In the interval of application the trend was : EY > AY > TY.

The EY SWS increased EC as compared with AY SWS and TY SWS. The EY SWS, TY SWS increased EC as compared to their respective application of other organic sources.

4.1.9.2 Potassium

The SWS recorded the highest k^+ value (0.096 me L^{-1}) which was significantly higher than all other treatments. It was followed by SWC which was, however, at par with FYM and PM. The interval of application showed trend of: EY > AY > TY. The EY SWS and AY SWS showed the highest K^+ content which was significantly higher than other EY and AY organic sources (Fig. 11).

4.1.9.3 Sodium

The effect of organic sources on Na^+ showed following trend : SWS = FYM = PM > SWC > CK. In the interval of application the trend was : EY > AY > TY.

4.1.9.4 Calcium + magnesium

The effect of organic sources on Ca^{2+} + Mg^{2+} concentration showed the trend of : SWS > SWC = PM = FYM > CK. The interval of application showed following trend : EY > AY > TY.

The EY SWS, AY SWS, TY SWS recorded higher values than their respective EY, AY and TY application of organic sources. The EY SWS showed higher value than AY SWS and TY SWS, the latter two being at par with each other.

4.1.9.5 Bicarbonates

The effect of organic sources on HCO_3^- showed the following trend : SWS = SWC = PM = FYM > CK (Fig. 12). In the interval of application the trend was : EY > AY = TY.

The EY SWS, AY SWS and TY SWS showed higher values than their respective EY, AY and TY application of other organic sources. The EY SWS increased HCO_3^- concentration compared with AY SWS. The AY SWS also increased HCO_3^- concentration compared with TY SWS.

4.1.9.6 Sulphate

The effect of organic sources on sulphates in SPE showed following decreasing trend : SWS > SWC > FYM = PM = CK (Fig. 13). The interval of application showed the following decreasing trend : EY > AY = TY.

4.1.9.7 Chlorides

The effect of organic sources on chlorides in SPE showed following decreasing trend : SWS > FYM = PM = SWC > CK. The interval of application showed the trend of: EY > AY > TY.

The results obtained showed that the SWS increased the EC, all cations and anions in SPE. The EY application of SWS had higher effect in increasing EC, all cations and anions. The SWC ranked second in increasing K^{+}, Ca^{2} + mg^{2+} and SO_4^{2-} content of SPE, while it was as good as FYM in respect of EC, Ca^{2} + mg^{2+}, K and Cl^{-}.

All sources increased chlorides and SWS increased sulphate in SPE of soil after harvest of first year sorghum (Shinde et al., 1993c). The SWS and SWC increased pH, EC, Cl^{-} and SO_4^{2-} content of SPE of soil after harvest of second year sorghum and the EY application showed higher effect (Shinde et al., 1995a). During third year of the experiment the SWS increased EC^{+}, K^{+}, Na^{+}, HCO_3^{-}, SO_4^{2-} and Ca^{2+} + Mg^{2+} in SPE of soil, while SWC ranked second in increasing K^{+}, Na^{+}, SO_4^{2-} in SPE of soil and as number of application increased the EC, K^{+}, Ca^{2+} + Mg^{2+}, SO_4^{2-} and Cl^{-} increased (Shinde et al., 1995b). During fourth year of experimentation, the SWS increased K^{+}, Na^{+}, Ca^{2+} + Mg^{2+}. HCO_3^{-} and SO_4^{2-} in SPE of soil after harvest of sorghum, while the SWC ranked second and the EY SWS and SWC showed higher effect (Ove, 1995). During fifth year (Gawande, 1996) showed that SWC increased EC, cations and anions in SPE of soil compared with all other sources. The effect of SWS Was comparable with SWC in respect of SO_4^{2-} concentration and SWC ranked second in respect of HCO_3^-.

During all the five years after harvest of sorghum and this year (sixth) after harvest of wheat increase in EC of SPE was observed by application of SWS. However, this increase was much below the critical limit of development of soil salinity (4 ds m^{-1}). It might be because of good drainage of soil was maintained as the plots were ploughed every year before sowing of sorghum as well as before sowing of wheat. So also the wheat being the irrigated crop every irrigation removed salts to lower depth.

4.1.10 Residual effect on physical properties of soil after harvest of wheat

Data of physical properties of soil are presented in Table 14. The effect of interval of application and interaction on hydraulic conductivity, water stable aggregates, and infiltration rate was not significant. Similarly, effect of organic sources, interval of application and interaction effect were not significant on bulk density.

4.1.10.1 Hydraulic conductivity (HC)

The organic sources resulted in higher HC than control. The highest HC was found in PM (3.11 cm h^{-1}) which

Table 14. Residual effect of spent wash solids and spent wash - press mud compost and their interval of application on physical properties of soil after harvest of wheat

i) Hydraulic conductivity (cm h^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	1.98	2.47	3.27	2.50	3.00	2.64	0.05	NS
AY	2.07	2.31	3.25	2.44	2.95	2.73		
TY	1.99	2.29	2.83	2.42	3.36	2.57		
Mean	2.01	2.35	3.11	2.41	3.10			

		Interaction	SEm ±	CD 5%
SEm ±	0.06	A x B	0.11	NS
CD 5%	0.22	B x A	0.11	NS

ii) Water stable aggregates (mm)

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	0.47	0.47	0.59	0.59	0.52	0.52	0.009	NS
AY	0.46	0.48	0.58	0.55	0.57	0.52		
TY	0.46	0.48	0.57	0.53	0.48	0.50		
Mean	0.46	0.47	0.58	0.55	0.52			

		Interaction	SEm ±	CD 5%
SEm ±	0.01	A x B	0.02	NS
CD 5%	0.04	B x A	0.02	NS

iii) Builk density (Mg m^{-3})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	1.33	1.20	1.25	1.27	1.35	1.28	0.014	NS
AY	1.33	1.22	1.30	1.25	1.31	1.28		
TY	1.34	1.25	1.25	1.25	1.28	1.27		
Mean	1.33	1.22	1.26	1.26	1.31			

		Interaction	SEm ±	CD 5%
SEm ±	0.02	A x B	0.03	NS
CD 5%	NS	B x A	0.03	NS

iv) Infiltration rate (cm h^{-1})

B\A	CK	SWS	PM	SWC	FYM	Mean	SEm ±	CD 5%
EY	2.68	3.96	4.23	5.11	5.86	4.36	0.20	NS
AY	2.83	4.13	4.43	3.51	4.32	3.84		
TY	2.10	3.22	4.06	3.86	3.83	3.41		
Mean	2.52	3.77	4.24	4.16	4.67			

		Interaction	SEm ±	CD 5%
SEm ±	0.3	A x B	0.46	NS
CD 5%	0.9	B x A	0.47	NS

was significantly better than FYM, SWC and SWS. The FYM ranked second, while the SWC was on par with SWS.

4.10.2 Water stable aggregates

Although PM showed the highest water stable aggregates (0.580 mm), it was comparable with SWC (0.550 mm) and FYM (0.520 mm). All these three treatments recorded higher stability than SWS which comparable with control.

4.1.10.3 Infiltration rate (IR)

The organic sources showed higher infiltration rate than control. The highest infiltration rate was found in FYM treatment (4.67 cm h^{-1}) which was followed by PM, SWC, SWS in that decreasing order.

The results obtained showed that the SWS and SWC were inferior to PM in respect of hydraulic conductivity and infiltration rate indicating ill effect of SWS and SWC on these properties. The SWC was as good as PM in respect of water stable aggregates, while SWS had no effect on water stable aggregates.

Improvement in stability in aggregate by all the sources, the HC by PM and FYM and porosity by PM and SWC was observed by Shinde et al. (1993c) after harvest of first year wheat. The FYM and PM improved HC and SWC improved infiltration rate, while higher stability of aggregates was found in SWC and FYM followed by SWS after harvest of second year wheat (Shinde et al. 1995a). During third year PM and FYM were better than other sources for improvement of HC of soil. The PM and SWC improved infiltration rate and was superior to FYM and SWS, while higher stability of aggregates was observed in SWC and PM treatments. The EY application of sources improved infiltration rate (Shinde et al., 1995c). During fourth year, PM and FYM decreased BD, HC, PM. The FYM and SWC showed lower effect on water stable aggregates than SWS, while all the sources improved HC of soil (Ove, 1995). The highest stability of aggregates by application of FYM was noted by Takate (1992) under pot condition. During fifth year results showed that FYM improved HC, IR and PM ranked second in these respects. The stability of aggregates of SWC, PM and FYM was comparable. The SWS did not show effect on stability of aggregates. There was not much effect of SWS and SWC on HC and IR (Gawande, 1996) during fifth year.

Summary and Conclusions

5. SUMMARY AND CONCLUSION

A long term field experiment was conducted from the year 1990-91 to study the effect of spent wash soilds and spent wash-press mud compost and their interval of application on yield, nutrient uptake by sorghum (*Sorghum bicolor* L.) (fodder) and wheat (*Triticum aestivum* L.) grown in sequence and on soil properties in comparision with PM and FYM. The salient findings of the residual effect on wheat and on soil properties during sixth year of the experimentation (1995-96) are summarized below :

5.1 Residual effect on wheat

5.1.1 Tillering stage

The SWS treated plot plants were nutritionally better in respect of N, K an Fe so also Zn which was as good as SWC. The PM proved better for P nutritional status of plants and effect of SWS, SWC and FYM was similar. All sources proved equal in respect of Cu and Mn in nutritional status. The EY and AY applciations proved better for N and P nutritional status, however, EY application proved better than AY application in respect of K, Fe, Mn and Zn. The EY SWS showed better N, K and Zn nutritional status of plants.

5.1.2 Flag leaf stage

The SWS established its superiority over other sources in respect of N, P, K, Zn and Cu, while SWC ranked second in Zn nutrition. The EY application proved better for N, K, Fe and Zn, while it was as good as AY in respect of Cu and P nutritional status of plants.

5.1.3 Residual effect on grain and straw yields

The SWS had significant residual effect on grain yield and EY application proved better.

5.1.4 Residual effect on nutrient uptake at harvest

The SWS, SWC and PM had equal residual effect on nitrogen uptake. The SWS was as good as PM in P and Cu uptake, while K and Zn uptake was higher in SWS. The Fe uptake was of second order in SWS and SWC. The EY application proved better, while AY application ranked second in uptake of all nutrients.

5.1.5 Residual effect on crude protein, crude fibre, soluble carbohydrate and crude fat content of wheat grain

The SWS increased crude protein content and decreased soluble carbohydrate of wheat grain. All sources increased crude fibre content. The EY application of organic sources increased crude protein content. The EY SWC proved better in this respect.

5.2 Residual effect on soil properties

5.2.1 Fertility status of soil

The SWS and SWC helped to build up organic carbon content of soil. All the sources showed equal effect on available P, Fe and Cu content of soil. Available K build up was found in SWS, the effect was, however, as good as FYM and PM. The SWS increased Ni, Co, Cd and cr content in soil, while SWC ranked second. Similarly, SWS increased available Zn content followed by SWC.

5.2.2 Composition of saturation paste extract (SPE)

The SWS increased EC, all cations and anions in SPE of soil. The EY application of SWS increased EC and all cations and anions over application of other organic sources. The effect of SWC was comparatively lower than SWS in increasing K^{+}, Mg^{+} and SO_4^{2-} content of SPE. It was as good as FYM in respect of EC, $Ca^{2+}Mg^{2+}$, K^{+} and Cl^{-}.

5.2.3 Effect on physical properties

The SWS and SWC were inferior to PM in respect of hydraulic conductivity and infiltration rate. The SWC was as good as PM in respect of water stable aggregates. The SWS had no effect on water stable aggregates.

From the results, it can be concluded that the use of SWS and SWC is possible without ill effects on yield of wheat and soil properties even upto six years of their use. Although use of SWS and SWC showed increase in EC of SPE which is much below the critical limit of 4 dS m^{-1} of SPE of soil for development of soil salinity. The review of literature indicated that the direct use of spent wash for crop production show ill effects on soil properties and in some cases on crop yield. The composting of spent wash with press mud, however, do not show such effects atleast when used on Sawargaon series with good drainage. Increase in heavy metals (Ni, Co, Cd and Cr) was, however, observed. It is, therefore, suggested that the experiment may be continued for on longer period to judge the ill effects of accumulation of heavy metals.

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* Orignals are not seen.

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