SUSTAINABLE METHODS AS APPLIED TO RAISING FRUIT CROPS

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PREFACE.

We had been doing work on Sustainable Agriculture on our farm for years. Our work involved cultural practices, which reduce cost and increase yields. It amounted to hit and miss trials until some success was achieved. The word Sustainable Agriculture coined later on in USA came as a surprise to us. We have sufficient records of four farms to prepare a useful write up of our experiences of failures and successes, and this has been prepared as brief summary of work done in the past 30 years. Since the past 5 years, very interesting results are coming out from the use of sustainable methods, as our new crops are starting to fruit.

The reason for starting the program was started to make use of cheap human labor, cheap availability of cattle manure, poultry droppings and all kinds of other agricultural waste materials readily available in place of costly machines, synthetic fertilizers and agricultural chemicals.

Further to this the following have kept the program going for 30 years:

- Economy of cultural practices.
- High yields of fruit crops.
- High returns.
- Challenging job, being first of the kind in Pakistan with no precedent and unexpected success met by us.
- Healthy soil.
- Less disease attacks due to healthy trees.
- Employment of local labor brings some prosperity.
- Indigenous innovations, researching and finding new techniques.

After above experience the present goal of the program is:

- To boost the sustainable methods for high yields in fruit crops.
- High returns.
- Create employment opportunities.
- Train other farmers and their employees.
- Open-up new opportunities of employment of agriculture university graduates in this field.

Program had been operating since 1965 on two crops namely mango and banana but a large scale planning and execution was started after 1990, when we had to introduce commercially new crops namely; lychee, longan, grape fruit, grapes, fig, pomegranate, apple, peach, nectarine, almond, pear and persimmon, in the low latitudes of sub-tropics (25º-27').

On experimenting with farm yard manure, human excrete, and compost, we had concluded that addition of these to the soil was much better than synthetic fertilizers in terms of enhancing yields, but farm yard manure increased weeds as it contained their seeds and compositing of materials on the farm and adding to the soil though economical, involved intensive supervision. We had reached the conclusion that if agriculture waste materials are spread as mulch under the fruit trees and mulch pile is maintained year around, yields would be higher than all other cultural methods. We therefore decided that in future mulching material would be produced on the farm between the tree rows and it will be mowed and spread under the tree canopy in a layer, 4 to 10 inches thick, depending upon the supply. The text gives the details, how annual weeds grow profusely in our area due to presence of their seeds in irrigation water year around. We also found that mulch suppressed the all kinds of weeds and applied continuously over some years, even notorious perennial weeds were killed, provided these weeds were mowed or pulled out, every time new mulch was added.

We grow trees on ridges 6 feet wide and 10 inches high and applied irrigation water in the rows between trees. Our soils are silty loam. Some thing un-believable has happened to the soil due to mulching. It has become porous to the depth of 10 inches. There is a tremendous activity of insects living on dry grass (mulch), their predators, and earthworms. On lifting mulch, the soil surface is seen fully covered with brownish-grey insects. Water is applied in the furrows between the tree rows and soil surface remains moist under mulch, even after 5 weeks of application. Tree growth is doubled and the first fruiting is early and so is first commercial crop. Recently 3 years old grape-fruit gave the first commercial crop and yield was the same, as the Pakistan's national average of mature trees 20 years old or older.

We are now training trees either to the central leader or to open vase systems. This is the first experiment of its kind in Pakistan. We are pruning trees to admit more light and thereby improve tree health and increase yields. By pruning 27 years old mango trees, we have increased their yield from 6 to 9.5 tons/per acre in 2 years again national average of 3 tons. Our yields were already double that of others due to advanced cultural practices.

We have established an Institute for Organic and Sustainable Horticulture and Agriculture Research. In this institute we will train other farmers, university graduates of both genders, in the sustainable agriculture methods in which we have already succeeded. We have produced 24 books on different fruits nuts and industrial crops the use of sustainable methods for raising them, in English language covering about 3000 pages. These will be published for use of teachers,

researchers, extension workers, farmers and students. Their translation in local language will also be under-taken as many farmers do not understand English. We plan to introduce Integrated Pest Management in immediate future. Presently we use pesticides only one a year during dormancy.

We hope the information in the book will be useful to the readers.

In the end we like to express our gratitude to Mr. Mazhar Yousif for volunteering to help in publication of this book and its proof reading.

Karachi,
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1. INTRODUCTION

In 1965, we purchased 108 acres of agriculture and near Khesano Taluka Hyderabad (Sindh) to produce fruit crops. Climatic data of Tando Jam 5 km from this farm are given in table-I. The map No.1 shows agro climatic zone of Sindh. We introduced banana and mangoes on 50 acres each and left 8 acres for trials on other fruits. The land was precisely leveled in one acre plots (264x165 feet) by using dumpy level and tractor having rear end blade. An embankment 2 feet wide and 18 inches high was also constructed around each plot to hold irrigation water. Roads each 12 feet wide and 2 feet high were also built around every 4-acre. Irrigation channels were dug along both sides of each road, running east to west. Flood irrigation was the cheapest method as water charges were at a flat rate of about Rs.5.00 (US1.00) per acre per annum, irrespective of quality of water used. We were getting 636 acre feet of water annually for 100 acres. In the beginning conventional method of flood irrigation was used. The Agriculture Extension and Agriculture Research Sections were not geared to proper advice on fruit crops, as these were new introductions then. There was lack of literature in Pakistan on cultural practices involved in fruit production. Most of the extension bulletins written by Karim-Dino Rajpur and were based on Hayes "Fruit Growing in India" a pioneering work, based on the study of common country practices over centuries and lacking scientific supporting data. There was lack of books not only in the university libraries, but also in the market or private collections of agricultural officers. The recommendations for fertilizers, were in terms of such and such number of baskets (of unknown size of Farm Yard Manure (FYM), so many kg castor cake, so many kg of cotton oil cake plus NPK (from urea, potassium sulphate and SSP or triple phosphate and so on). The recommendations did not specify total fertilizers in terms of N_2, P_2O_5 and K_2O per tree per acre per annum.

N = Nitrogen, P = Phosphate and K = Potash
N_2, P_2O_5 and K_2O are also used as symbols for all above three ingredients.

The Agriculture Department's recommended spacing for mango was 45x45 to 50x50 feet. The inter-space was to be used for inter-cropping to support costs involved in raising orchard. For Cavendish bananas recommended spacing was 6x6 feet and each mat having one mother plant and one sucker. For weed control of banana and mango, clean cultivation was recommended.

A fleet of laborers with local spades (about 10-12 inch wide hoe) were to inter-cultivate soil to a depth of 4-6 inches and repeat operation when weed growth became 5"-6" tall. In the climatic conditions as at Khesano shown in table No. I, weeds grow very fast and some 5-6 inter-cultivations were done under the

mango tree canopy and 2 feet out side it. The inter-space between mango trees was cultivated with tractor. Inter-crops planted were; cotton in 1965 and 1966, wheat in 1965, 1966 and 1967/68, alfalfa (Lucerne) in 1967-1970, papaya in 1970-1973 and pepper in 1974-1975. The prices of cereals, cotton, animal products (milk and meat) as fixed by the government, were so low that costs of inputs or even managerial costs could not be recovered from the inter-crops. The wider spacing in mango was a folly. By 1977 we felt that even 41x45 feet spacing adopted by us for mangoes was too far apart and planted one tree at centre of every four trees, doubling the tree population and reducing diagonal distance between trees to 30 feet. The new plants interfered with old plants only 15 years later, when a pruning program was launched and every year pruning was done so that at least 25% of ground under the trees gets sun-light at mid-day. After 3 years heavy pruning has been limited to light pruning only, except for top working.

Farm Yard Manure (FYM).

Before applying FYM we had soil samples analyzed for NPK. FYM was readily available from near by villages, where animals were raised for draft, meat and milk and manure was collected for applying to the land. FYM was collected by villagers either from barn or from wild pasture lands, where animals grazed. In general it was free from urine, but contained weed seeds, browsed from the wild. Its age was about one week to 3 months. As it was purchased by volume about 800 cubic feet of it made a truck load of 8 to 10 tons: N: P: K contents in it are shown in Table-II below:

Table – II SHOWING MACRO-NUTRIENTS (N: P: K) COMPOSITION OF FYM.

Ingredient	Percentage in the FYM	Ingredients per 8 ton truck load in kg.
N_2	0.4	32
P_2O_5	0.2	16
K_2O	0.2	16

The Department of Agriculture was recommending 4 truck loads of FYM per acre per year. In general this would meet the N_2 requirements of banana per acre but not of K_2O, which had to be applied as extra. FYM decomposes slowly and only some 25% is utilized during the first year and therefore synthetic NPK chemicals had to be applied in addition. Continuous applications of FYM year after year do meet N_2 requirements, but decomposition of fresh material creates N_2 shortages of FYM must be applied in early winter when up-take of nutrients is low due to dormancy.

The Department recommended that all extra suckers, leaves and banana stems that have been harvested may be removed from the field, immediately as they contain lignin which will not be digested and will cause unnecessary problems and in addition may harbor bacteria, fungus, insects and damage bunches. We did what was recommended, although we were not convinced. The removal of material was costly. It took years to digest it in open and caused space and environmental problems.

Human faeces.

We had an idea that human faeces (without urine) were collected by "sweepers" and dumped out side the city of Hyderabad to dry and serve as landfill. The Municipality of Hyderabad allowed us to carry it away at Rs.5.00 (US$1.00) per trailer of 5 ton capacity. The material usually was a week to four weeks old and was hauled with the help of front-end loader and tipping trailer. Four week old material was not smelly but one week old material had smell.

The macro nutrients content in a sample of this material is shown in Table-III below:

Table – III ANALYSIS OF HUMAN FAECES.

Ingredient	Percentage in faeces	Ingredients in 5 tons in kg
N_2	4.5	225
P_2O_5	5.5	275
K_2O	1.2	60
Ash	12	600
Water and other volatile material.	76.8	3,840

This material was better in the terms of ingredients and although each round trip from dump yard to land took 5 tractor-hours or Rs.80 (US$16.00) per 5 ton load, but ingredients in it made this material cheaper than synthetic fertilizers or Farm Yard Manure. It was poor in K_2O and supplementary K_2O was applied to banana and mango. Material was stocked on the roads until it lost smell and contractor used donkeys to spread it where needed.

Poultry manure.

We also found that banana suckers, leaves and steams could be composted by adding N_2 in any synthetic form as well as F.Y.M., human faeces and poultry manure.

We had poultry manure analyzed and found the following percentage of various ingredients.

Table – IV INGREDIENTS IN POULTRY MANURE.

Ingredient	Percentage in poultry droppings	Ingredients in 8 tons truck load in kg
N_2	1.2	96
P_2O_5	5.5	440
K_2O	1.2	96
Ash	12.0	960
Organic matter	22.0	1,760
Water	53.1	4,648

Poultry manure has large quantities of phosphates, which are unavailable in Khesano soils due to high pH, but the nearest pH poultry houses were about 160 km away and hauling cost was exorbitant.

Micronutrients.

Oil cakes are used as animal feed in Pakistan and are costly and therefore were not tried. The farmers were using large quantities of synthetic fertilizers and F.Y.M. In Thatta district climatic conditions were highly suitable for banana and though yield of 10 tons per acre were achieved yet nothing was scientific. Macro-nutrients were invariably applied in excess. There was no concept of micro-nutrients. The research facilities of the Government were not equipped to analyze micro-nutrients in soils and plant tissues. Private laboratories did not exist. The yields, therefore, had become stagnant. By removing banana waste materials, heavy amounts of potash were removed and these were not fully replenished by farmyard manure, which by 1980 had become too costly to use, as area under banana had hit 150,000 acres and mango about 100,000 acres from negligible in 1960.

Inter-cultivation of Mango and Banana.

We also found that the yield of mango was a maximum of about 3 to 4 tons / acre, against 10 tons / acre in Florida, Australia and South-Africa and to increase yields sustainable methods had to be practiced.

We also had noted that inter-cultivation of mango and banana 6 inches deep, by local spades (hoes) was cutting down feeder roots within 6 inch depth and plant

had to transfer some energy to regenerate these roots, instead of suing the same energy for canopy growth and fruit development.

For the removal of banana suckers, leaves and stems, a full-time person was needed for every 2 ½ acres. Inter-cultivation 4-5 times a year on contract basis was taking about 32 man-days per acre. Banana waste was taken out from every 4 acres and dumped on nearest road, which in no case was more than 165 feet away, composted and put back in the field by donkey labor. Putting FYM or compost back in the field and spreading it, took 4 man and 2 donkey days per acre. This reduced profits. Another factor that was playing its role was the area under bananas in Sindh had increased from nothing in 1956 to 150,000 acres in 1980 and sale prices had come down to about 50%, where as Government subsidies on fertilizers and pesticides were being gradually withdrawn. There was inflation and urban labor problems. The Government instead of raising labor wages fixed the procurement prices of wheat, rice and cotton, very low, so that urban population and labor gets food and clothing very cheap. The purchasing power thus was reduced and so the prices of fruit. The growers margin was reduced so much that they could not afford to spend any amount on development or bring new areas under fruits or changing cropping patterns.

We also understood that continuous inter-cultivation had disturbed level of land in mangoes and the recommended practice of earthling around banana stems had caused depressions between the plants. Mono culture of banana and mango had proved disadvantageous to the growers. There was glut of bananas from October to March and shortage for next 6 months. Our first act was to replace Cavendish Dwarf with Cavendish Giant (Williams) and regulate its suckers to fruit in summer months. We could harvest about 75% crop in summer and get double the prices and 25% in winter at normal price. Another action was to visit Florida, California, Texas, Georgia. Hawaii and Australia to find out new crops, which can be grown in our areas, so that we do not sink in the mono-cultures. We also collected each and every bulletin issued by Extension Organizations of various countries of the World and the States in U.S.A., and any books on fruit culture or new fruits.

In the past 15 years we have collected 11,000 books and bulletins, established an office where 6 ladies (M.S in various branches of sciences) studied this material and organized a kind of office seminars to understand new methods in sustainability of agriculture and increasing yields. We also engaged M.S (Agronomy), as farm managers, supervisors and foremen to execute the plans prepared in the office.

The other farmers engage untrained and uneducated supervisors who control labor by use of force and threats.

Following are the field trials on sustainable methods, commercially successful on our 108 acre farm and results there of over the past 30 years.

Table – I SHWOING THE AVERAGE MONTHLY CLIMATIC DATA OF TANDO JAM.

Month	Evaporation (mm)	Sun-Shine Daily Hours	Rain Fall (mm)	Temp. Maximum (°C)	Temp. Minimum (°C)	Temp. Mean (°C)	Relative Humidity (%)	Dew Point (°C)
January	25-50	8.50	5	22.8	8.3	15.5	50	3.9
February	75-100	10.00	5	28.3	10.5	19.5	50	7.2
March	150-175	9.25	5	32.8	16.6	24.5	50	10.5
April	200-225	10.75	2.5	38.9	21.1	30	50	13.0
May	225-250	10.50	5	42	25.5	33.9	5060	19.5
June	175-200	10.00	10	39.5	27.2	33.3	70	24.1
July	175-200	8.75	75	37.0	26.6	31.6	70	22.2
August	175-200	9.00	50	36.5	25.8	30.5	60	20.2
September	175-200	10.50	15	36.8	24.5	30.2	60	20.5
October	125-150	10.50	0	35.5	19.1	27.5	60	15.0
November	50-75	10.0	2.5	32.2	13.4	22.8	60	9.0
December	50-75	9.0	2.5	25.5	9.0	17.2	60	6.5
Annual Mean	1950-2000	9.72	177.5	34.0	19.8	25.8	57.50	19.7

2. UNSUSTAINABLE AGRICULTURE, SYNTHETIC FERTILISER APPLICATIONS TO BANANA

With use of synthetic fertilizers, the yield of banana came down and over the first four years from 5.8, 8.1 and 7.05 tons to average of 6.1 tons in the years 4. Subsequently, it fluctuated between 5.7 to 6.35 depending on severity of cold in winters. Temperatures below 5ºC for a few nights continuously usually destroyed chlorophyll in leaves and delayed flowering next year. Late flowering usually produced small bunches and low yields. It was concluded that lowering of yield year after year was caused by reduction of organic matter in the soil as well as cutting down of feeder roots by inter-cultivation and removal of more potash in the banana stems, leaves and suckers, than applied in form of synthetic fertilizers. Application of 2 bags of potassium sulphate instead of one every month from first March to first October reduced chlorophyll destruction, but

yields remained low. We therefore decided to switch over to adding organic matter in different forms discussed in the next chapters.

3. USE OF FARM YARD MANURE (FYM) AS SOURCE OF NPK AND MICRO NUTRIENTS IN FRUIT CROPS (1970-74)

In the introduction, Table-II, the chemical composition of FYM has been discussed.

In the South-Asia use of FYM goes back to antiquity and it is invariably used on all kinds of horticultural crops. We did like-wise, but finding high cost of collecting, buying, transporting to the field and applying it to trees / plantations by donkey labor; we gave it up in favor of synthetic fertilizers and weed control by hoeing. After some years we found that yields had either decreased or at the best had become stagnant.

We, therefore, reverted back to the use of FYM and quantities applied were worked out from NPK content of it as given in Table-II. Knowing the FYM takes 2-3 years to digest, N2 in form of urea equivalent to N2 in FYM was added to mango and a year's dose was applied once. In case of banana 4-truck loads of 8000 kg each were, applied in November and half bag (25 kg weight) of urea were applied 4 times in November, March, June and September and in case of mangoes in March and continued for some years. FYM created weed problems by bringing new weed seeds and invigorating the existing ones. Suppression of weeds was a costly problem and FYM, its transport to the site and spreading under crop was also equally costly. Yet it improved tree growth and yield of banana increased gradually over a period of 4 years from 6 to an average of 8.8 tons / acre in the year four and then became stagnant.

In case of mango there was improvement in growth and health of trees but they still had not reached maturity and yield was increasing year by year and its comparison with controls could not be quantified as different trees showed different yields. However, annual increase in trunk and canopy diameter was more in trees receiving F.Y.M. The reason probably was that FYM took nitrogen from soil possibly over the whole year for its decomposition and supply of synthetic fertilizers was not uniform enough to compensate soil nitrogen deficiencies for the whole year. Nitrogen made available from FYM, was also not uniformly spread through out the year. The organic matter built up was also gradual. In four year period annual application of FYM allowed building up of organic matter in soil and supplies of macro-nutrients became uniform and the yields established. The yield for the years were; 5.8, 7.7, 8.2 and 8.8. In the

subsequent years yield fluctuated between 8.4 to 9. This shows that benefits of FYM are available after 3-4 years.

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The Conclusion.

- It was apparent that use FYM alone or with supplemental NPK from synthetic fertilizers was better than chemical fertilizers alone, in terms of tree trunk and canopy growth of tree crop and also yield.

- In case of banana it increased yield when supplemented with chemical fertilizers. Yield increase was gradual and attending over 4 year period and no further increases occurred, possibly as FYM promoted weed growth.

- FYM brought new weeds and invigorated existing ones. There is extra expenditure on weed control.

- Application of FYM involved hauling of bulky material from a distance and applying it to individual trees, but the cost involved was paid back by extra yield. It also absorbed extra managerial charges.

- Weedicides are killers of soil fauna and ultimately result into soil deterioration and we were not using them, except during first few years. Mechanical methods were better than herbicides though continuous use of machines injures the soil.

- FYM helped in producing healthy soil and healthy trees, but weed problem multiplied.

- Synthetic fertilizer when used alone, reduce yield year after year, due to soil exhaustion.

Use of Farm Yard Manure (FYM) as source of NPK and Micro Nutrients in Crops (1970-74).

- FYM has low pH and in our soils of high pH of + 8.0, it produces local lowering of pH and thereby up take of micronutrients from soil.

- FYM besides NPK also supplies micronutrients which help increasing yield.

4. COMPOSTING OF BANANA TRUNKS, LEAVES AND TRASH BY ADDING UREA AS CATALYST AGENT

The Department of Agriculture were recommending that dead leaves, banana suckers and stems, should be taken out of the field and thrown away as they cannot decompose if left inside the plantation. In the year 1965 and 1966, these were taken out and dumped in dry pit. It was true that they did not decompose in 2 years but lost water by evaporation and lay there as a pile of fibrous matter. We decided to add urea and water to it and cover the top with 6 inches layer of earth. It was found that pile had started shrinking and after about a year there is no further change in size of pile. We removed the earth and found that material had turned into small pieces by anaerobic digestion. We were now certain that banana wastes can be composted and reused.

We, therefore, took out banana, waste materials from the field chopped them in pieces 6 inch long and when pile become one foot thick, urea was added on the top and another one foot layer of banana waste was laid and urea added. In this way the pile was raised to five feet height. No water was added as stems contained adequate moisture. The pile was turned over every 3-4 days, as it was feared that water in the waste material will leach down, taking away nutrients with it-self. In a month's time the pile shrank and rather was less moist. The pile then was turned over every week and moisture added, if needed. After 16 weeks it was found that the pile was no longer shrinking further and it no longer generated heat inside, showing that process of composing was complete. The time of year was mid March to mid July having mean monthly, temperatures of 24.5, 30, 33.9 and 33.3ºC and diurnal ranges of 11-17ºC.

This material was used in place of FYM in banana field and was supplemented by 2 bags of urea, 4 bags each of potassium sulphate and SSP, each bag weighing 50 kg. It was digested very fast and no traces were visible after 12-16 weeks depending on the season. The banana yield also increased to an average of 9.3 tons / acre while the control which were getting only N.P.K., in form of 8 bags urea, 8 bags potassium sulphate and 8 bags SSP, each bag weighing 50 kg, were not giving more than 6 tons / acre as an average.

5. COMPOSING OF FARM YARD MANURE (1970-74)

We had been applying FYM to fruit trees as source of nutrients as well as source of organic matter. FYM source was excreta of cows and buffalos. These animals

browse on wild growth in pasture lands, near the village. This FYM therefore, contain seeds of various wild grasses and weeds and in spite of helping tree growth, weeds growth, is enhanced and becomes problematic even after FYM is digested under crops. The weeds are both perennial and annual and once established recurrence is year after year.

To eliminate weed seeds, it was decided to compost FYM so as to kill these seeds before its application to banana plantation and mango trees. Farm Yard Manure available to us was fresh as well as partially dry, but the latter was not more than 3 months old. It was mixed with farm wastes like banana stems, leaves and suckers and leaves and twigs of mango trees and weeds growing along roads and watercourses.

Since we were using about 250 truck loads of 8 tons each or 2,000 tons of annually, it was brought and dumped on the roads in the farm and waste material mixed with it. Since C:N ratio in the material was low, ¼ bag of urea was added to each truck load of FYM and water sprinkled on the pile to help in decomposition, compositing was done through out the year and compost was applied to banana and mango by contractor using donkeys. Compost pile height was about 5 feet at the start and it was turned over manually every third day and process continued until no further heat was generated in the pile. In summer months when day temperatures were over 40ºC (average maximum of May being 42ºC) temperature in the pile would easily exceed 60ºC and seeds would lose viability. Even in winter the pile developed enough heat that seeds were made non-viable. Compost was found better than FYM as its volume was much less. It could be safely stored in open on the roads in arid climate of Sindh and applied to the field when needed. It acted fast and did not promote new weeds. However, weeds already growing under mango trees and in banana plantation appeared to have been invigorated due to extra nutrition from the compost. Compost had low pH and probably helped in up take of nutrients from soils it was in contact with. It killed juvenile mango trees if applied in excess. It also burnt bark of young trees if it touched the trunk. The tree health improved as compared to use of synthetic chemicals, because of micro nutrients present in the compost. Soils of Khesano are deficient in zinc, copper, iron, boron and manganese. These micronutrients were imparted by compost as random analysis of samples had confirmed.

In terms of cost, application of compost was costly because the waste materials had to be brought out from the field, to be mixed with FYM. Piles usually consisted of one truck load of FYM (8000 cubic feet) and almost equivalent quantity of trash was added. Usually there were 60 piles to be turned over every third day and 8 full time laborers were used. To take trash out from the field 3 other persons were busy year around. This made operation very costly.

Applying 4 truck loads of FYM in the composted form to banana increased yield by about 73% i.e., from 6 to 10.4 tons per acre. The extra yield covered the cost of labor as well as raw materials i.e., FYM and trash. Compost from 4 truck loads of FYM was applied to each acre per year in 4 equal split applications. With each application ¼ bag urea and one bag of potassium sulphate but no SSP was applied. There, however, was a disadvantage that existing weed, growth became profuse due to extra nutrients. The operation was considered as success, as it was a profitable proposition. It was better than using farms yard manure alone or using only synthetic fertilizers. It was labor and management intensive and was keeping field staff on toes and overall management too alert.

6. USE OF BANANA FIELD WASTE MATERIALS AND HUMAN EXCRETA FOR COMPOSTING (1973-1979)

The city of Hyderabad having population of 1.8 million did not have drainage system and bath rooms in the houses were designed for collecting of faeces by sweepers daily. The faeces were dumped in pits outside the city and land fill. Knowing fully that these will be rich in NPK and micronutrients, we entered into contract with Hyderabad Municipality to haul this material away at rate of Rs.5.00 (US $0.50) per 5 tons trailer. It was period of banana boom. All farmers surrounding our land were growing banana. They had space problem for dumping stems, leaves and suckers as Agricultural Extension was advising for removal of these. We had successfully composted the material with urea and FYM and asked them to dump the material on the roads surrounding our land. These 15 feet wide roads were about 8,000 feet long. In addition we had internal roads around each 4 acres. We hauled faeces with help of front end loader and a covered tipping trailer from a distance of 15 miles (25 km). The banana stems and leaves were chopped to 12 inches pieces for composting. After every 12 inches layer of banana waste a 3 inch layer of faeces was put by front end loader and piled until 8 feet high. No water was added as banana stems contained sufficient moisture. These piles allowed sufficient aeration because of nature of banana waste. Composting was very fast and in 3-4 weeks when pile reduced to 5 feet height, it was turned over by front end loader. After first turning over, it was no longer smelly and labor turned over every 3 days. Composting was complete in about 3-4 months. We used the material for our orchard. Since it was in excess of a year's needs it was stored under sheds made from local materials at the farm.

We used the compost in banana at rate of 10 tons per acre per year and without use of supplemental N_2 or P_2O_5, but added only 4 bags of potassium sulphate annually. The results were the same as with 4 truck loads (32 tons) of FYM composted with banana waste and supplemented with 4 bags (of 50 kg) of each

urea, potassium sulphate and SSP. The cost was less as less material had to be spread in the field.

We continued composting this material until 1977, when the Hyderabad city was provided with drainage and faeces were no longer available.

The stored material was used fro next 2 years, when we decided to use banana trash as mulch, as all other methods, involved expenses on hauling bulky materials.

7. COMPOSTING POULTRY DROPPINGS

In 1987 poultry houses were established within 5 miles (8 km) of our farm and we thought of using it on the farm. Analysis showed that, N_2 in it is about three times, P_2O_5 about 27 times and K_2O about 6 times, those in Farm Yard Manure. Its cost is about triple that of FYM.

We brought a few truck loads to compost it with weed clippings from the farm. It composted much faster than FYM to which urea was added to improve C: N ratio but the end product had very high percentage of P_2O_5. We used the material in the holes dug for new trees, so that phosphate supply last longer, but its use as NPK source will provide excess doses of P_2O_5 and therefore it was not used.

It is felt that composted poultry droppings can be mixed with composted FYM to reduce P_2O_5:N_2 ratio in the mixture and applied to fruit crops.

We used poultry droppings in bio-gas plant and residue after drying was fit for animal consumption. It was handed over to a party to be mixed with fodder and used as cattle feed.

8. USE OF BANANA FIELD WASTE MATERIALS AS MULCH IN CROP (1979-1990)

In 1979 we decided to replace Cavendish Dwarf with Cavendish Giant (Williams) as it could fruit in summer months against winter season of the farmer. We had raised enough suckers for 50 acres and while replacing the varieties all waste material consisting of suckers, roots, leaves and stems of Cavendish Dwarf was removed and piled on the roads. Land was precisely leveled. Immediately after replanting, the waste material was spread on the ground as mulch and any extra suckers or dead leaves from new growth were also spread between the plants. These suppressed weed growth and first harvest

started after 18 months. At the end of first harvest the mulch layer was about 5-6 inches thick and continued to remain so, for the next 10 years. From 1980-1990 bananas waste materials like suckers, dead leaves and stems were chopped in pieces 12 inch long and spread between the plants. It was also found that mulch reduced evaporation from soil, which remains moist for longer time than un-mulched area and therefore instead of irrigating every week in summer, frequency was reduced to 10 days interval; in spring and autumn from 10 days to a fortnight and in winter from a fortnight to 3 weeks. This not only saved 33% irrigation water but reduced seepage losses of nutrients to ground water table and also reduced costs of inter-cultivation and cost of labor spent on removal of leaves, suckers and stems out of the field.

The outstanding advantage of this was that large quantities of potash in the waste material were returned to the soil. Since the decomposition of material was very slow, leaching of nutrients in the mulch was reduced. The practice was continued over next 11 years. The yield shot up to an average of 13.8 tons per acre per year. Soil samples were examined for lignin content. Lignin kept increasing for the first 5 years and from 6th to 11th year it remained stable, showing that even lignin gets digested in about 6 years, if adequate moisture and nitrogen is available in the soil. Since no inter-cultivation was done, land level remained precise and light doses of irrigation were found adequate. The mulch also reduced soil temperature in summer and increased them in winter, resulting into better growth and higher yields. The fertilizer dose was also reduced to half. Since the mulch had high C/N ratio, one 50 kg bag of ammonium nitrate was applied every month from 1st March to 31st October and one bag of potassium sulphate and S.S.P., every second month from March to October i.e., 8 bags of ammonium nitrate and 4 bags of S.S.P., and potash each weighing 50 kg. There was saving on the cost of fertilizers as well as labor. The results came to the notice of neighbors; some of them adopted this practice. From the results obtained, we concluded that mulching is the best method for disposal of banana waste materials and should be done for all fruit trees. It is also most economical way for disposal of banana waste material.

When banana stems, leaves suckers were used as mulch instead of being taken out, the yields in the first year came down. It was quite understandable that the large quantities of organic matter deficient in nitrogen chopped and left on the ground will take N_2 from soil for their decomposition and the amount of N_2 applied in form of synthetic fertilizers can not be regulated to meet uniformly the N_2 demand of this matter. This will then be provided by soil. The supply of organic matter and its quality also fluctuated. The material from discarded suckers was available mostly in spring and autumn. About 75% stems were available for mulch between April and September immediately after harvest of each stem and only 25% in next six mounts. Leafy material was available mostly

in summer months and again in spring. The decomposition was maximum in summer and very little in November to February. The N_2 requirement, for decomposition of waste materials therefore, fluctuated and shortages occurred. In four year's time, it got balanced enough to give uniform yields but during the first year yield came down and gradually rose. After 4 years yield became uniform due to building up of organic matter, its uniform requirements and supply of N_2 from soil as well as from organic matter.

We found that yield started increasing and after the third year, it stood at 13.8 tons per acre against 6 tons. When NPK were applied in the form of synthetic fertilizers. Main advantages of spreading banana trash were:

- Trash worked as mulch.
- Weeds were suppressed totally.
- Ground remained moist under banana wastes and water application frequency was reduced in summer from weekly to every 10 days, in spring and autumn from every 10 days to every 3 weeks. In the coldest month of the year i.e., January, only one irrigation dose was applied in the first week of January.
- Seepage reduced and so did nutrient leaching.
- Trunk height and diameter became bigger than all other methods.
- Suckers threw flowers much earlier i.e., in the 13-14 month as against 16-20 months by other methods.
- Bunch size, weight, number of hands and fingers increased.
- There was better acceptance of bunches in the market.
- Rejected fruit was much less.
- While walking on soil it showed a kind of resilience or elasticity.
- Twelve years later banana was destroyed by Bunchy Top Virus and we had to plant other crops like lychee, longan, grape fruit, grapes and pomegranate on the same land. We found soils highly enriched and their growth clearly showed the difference with the same fruit crops grown out-side banana area.

- Mulch besides providing nutrients had reduced ground temperatures in summer about 10C and raised them in winter by about 7C., but this varied with thickness of mulch, as well as whether it was directly exposed to sun or not.

- The cost of inter-cultivation, taking banana waste out-side and putting compost or FYM back was saved.

- There was enough waste material that a layer of 3-6 inch mulch could be maintained year around.

- It proved to be highly profitable method in banana culture and we extended the system to the other trees crops by chopping weeds and using them as mulch.

9. MICRO-NUTRIENTS IN BANANA

Sindh soils are highly deficient in zinc, as the area was under rice crops for at least for 3,000 years. Water which comes from the river Indus has pH of 7.4 and soil pH is 8.0. There micro-nutrients were sprayed on foliage every March and September at rate of 1 kg zinc sulphate 1 kg copper sulphate, ½ kg manganese sulphate, ½ kg boron and 1 kg iron sulphate. The yield started increasing and in 1989 stood at 14.6 tons per acre. The Banana Bunchy Top Virus destroyed all plantations in 1990 and it could not be confirmed if micronutrients applications sustained the yields or it was merely favorable climate of the year. We concluded that the magic was mulch and micronutrients too have their own place, but they are too having their own place, but they are too costly except sulphates as foliar sprays.

10. USE OF BANANA WASTE AS MULCH IN BANANA FIELD AND ADDITION OF MICRONUTRIENTS

The Department of Agriculture had been recommending clean cultivation as a method of weed control in banana plantation. We had been fully convinced of the disadvantages of low yields connected with inter-cultivation banana with hoes and virtually digging the ground to a depth of 4 to 6 inches and cutting down the feeder roots, leading to low yields. Four truck loads of FYM, when applied to banana per acre improved yield but aggravated weed problem and brought new weeds present in FYM. Applying composted FYM, made seeds non-viable, but existing weeds invigorated after application. Though in any case it was better than applying FYM.

We planned to cover the whole ground in banana field with chopped banana stems, leaves and suckers and apply N_2 to help in digestion of this matter. To our surprise the trash was sufficient to cover the ground to a depth of 5-6 inches and as it was being digested, enough new material was available to maintain 5-6 inches layer of mulch year around. We applied 4 bags of each of three fertilizers urea, potassium sulphate and SSP every second month starting from mid-March to end September to cover losses due to removal of crop and leaching down of nutrients with flood irrigation. In order to supply nutrients 7 kg of zinc sulphate, 1 kg of copper sulphate ½ kg of manganese, ½ kg of boron and 1 kg of iron sulphate were sprayed on the banana trash uniformly per acre area. It was assumed that trash will have low pH and it would make uptake of nutrients easy. After a year, leaf analysis was done and micronutrients added as needed.

We found that yield started increasing and after the third year, it stood at 14.8 tons per acre against 6 tons when NPK where applied in the form of synthetic fertilizers.

11. BERSEEM CLOVER AS MULCH AND FOR WEED CONTROL

The Department of Agriculture recommended clean cultivation in the mango and other fruit tree orchards. We accepted the recommendation and did clean cultivation i.e., ploughing down weeds every second month in 50 acre mango orchard. The operation was very costly. Since the area is arid and regular irrigation is practiced, weeds grow all the year around. New weeds are also brought by irrigation water the source of which is the river Indus. The river over-flow its banks in summer and spreads within leaves 10 miles (16 km) apart. All kinds of weeds grow within levees and their seeds are picked up by river water. Irrigation water then distributes them; where-ever it is applied.

To get rid of weeds we planned to grow berseem clover between trees and used it as mulch as well as a source of nitrogen. Planted in October the first cutting was taken in December and piled under mango trees as mulch. Subsequently cuttings were taken every 3 weeks and used as mulch. This was continued until March 20th and on April 30th, clover was ploughed in. The results were as under:

- Clover suppressed weed growth in winter and spring (March-April), but weed competition was never severe in winter.

- Cutting clover manually from 50 acres, 5 times and ploughing the final growth in, was very costly. A labor force of 20 persons was needed full time from December to March to cope up with the task.

- Mulch did help tree growth and health, but mango trees became too vigorous and first fruiting probably was delayed and yields reduced.

- The weed problem was more severe after clover was ploughed in, as new weeds brought by irrigation water got fertile seed bed.

- After berseem no new crop could be planted in the inter-space between the trees, as mangoes were in fruit and harvest time was May to July.

- After one year trials this practice was stopped as un-economic.

- Other farmers, who raised berseem in mango orchards and sold first 5 cuttings to cattle farms, were able to save money and for them it was economical but fruit growth was retarded as berseem was competing with mango roots for food.

- The prices of meat and milk as fixed buy the Government are very low and only raising animals on natural pastures are economical. Under such circumstances inter-cropping or rising of fodders between trees is marginally not advisable in Pakistan.

12. APPLICATION OF MICRONUTRIENTS TO FRUIT CROPS

It is known that lack of micronutrients in food can create health problems in human and animals. For example:

- Deficiency of manganese can cause mental retardation, vestibular dysfunction, back problems, degenerated discs schizophrenia, epilepsy, lowered learning ability in children, alcoholism, Wilson's disease, Pick's disease, cerebral motor functions, membrane instability, impaired growth, reproductive problems and shortened life span.

- Zinc deficiency causes lowered learning ability in children, apathy lethargy, Wilson's disease, achrodermatitis enteropathica, schizophrenia, impairment of DNA, RNA and protein synthesis, amnesia, mental retardation, irritability, depression, paranoia, anorexia and loss of hair.

- Iron deficiency may cause anemia, poor growth, lethargy, blanching of mucous membrane, increased heart and respiration rates decreased resistance to infection.

- Copper deficiency causes rapid growth of off-springs as a result of prenatal or neonatal deprivation, deprived appetite, decreased growth rate depigmeniation of hair and anemia.

Soils in our area have high pH (8.0 – 8.5) and in such soils uptake of manganese, zinc, copper, iron, boron and molybdenum is retarded. We therefore made a plan to apply these elements to fruit crops by foliar sprays after detailed leaf analysis. The purpose was to produce healthy food for people, but result was that besides healthy food the yield increased substantially. Presently our yield for most of fruit crops compares favorably with those of California, Florida, Hawaii, South Africa and Australia, and are 2.5 to 3 times yields of even the progressive farmers using synthetic chemicals only.

(**Ref:** Journal Orthomoleular Phychiatry Vol. 16, No. 4, 1977, Vol. 9, No. 4, Vol. 12, 1983 for diseases due to lack of micronutrients).

13. FALLEN LEAVES FROM MANGO AND OTHER TREES

Different fruit tree leaves have different life and in case of mango old leaves usually fall down in January to March, at the time of flowering and fruit formation. The Agriculture Extension had been advising that these leaves carry diseases and must be removed from the field. We agreed with them that they carried over diseases like anthracnose, Bacterial Black Spot, Stem End Rot and etc., but leaves fall over a period of about 2 months and sweeping the ground of debris, on 50 acres was impractical. Exactly at this time we cut down weeds and waste materials growing in the mango orchard. This material was adequate to provide 2-3 inches cover under the mangoes and act as mulch. The timing also had coincided with annual application of pre-flowering fertilizers (synthetic or FYM or compost). We simply put the mulch above the tree leaves and applied irrigation water. High temperatures from 1st March to 15th April digested all the material. To take the leaves out it would have taken 6 weeks in any case. We considered this as the best solution to disposal of leaves and return of nutrients to the soil.

We were already taking care of fungal diseases with copper sprays and incidence of disease remained within tolerable limits.

This is now a general practice of disposal of leaves year after year.

14. IRRIGATION AND WATER INFILTRATION

The lands in Pakistan are not precisely leveled. The common method of irrigation is by flooding. We found that all farmers are dividing each acre in 4 or more parts, providing embankments around each plot, irrigating the highest portion first and breaching water from it to lower level plots rather than taking channels to each small plot individually. This was not an efficient method and we therefore, divided our land in one acre plots, precisely leveled it and irrigated it as one acre piece from one out-let.

Irrigation water contains about 250 parts of salt per million parts of water and although we were applying only 2 ½ inches water every week in summer, every 10 days in autumn and spring and every fortnight from November to end February, the total water applied was:

- 1st April to 30th September (26 weeks). 65 inches
- March and October (6 irrigations). 30 inches
- November to February (8 irrigations). 20 inches

115 inches

The pan evaporation was about 80 inches and evapo-transpiration about 51-60 inches with different crops.

Thus about 50-55% water was added to water table annually. This water was causing many problems like:

- Reduction in growth.
- Affecting tree vigor.
- Reduction in tree yield.
- Fruit quality impairment.
- Reduction in tree longevity.
- Increase in disease susceptibility.

- Impairment of soils.

- Leaching down of fertilizers causing reduction in fertilizer availability to the plant, polluting ground water with nitrates phosphates and potassium salts. That leaching down of salts from soil is essential and some allowance had to be made, because 115 inches of water per acre would contain 1242 cubic feet of salt, enough to form 0.35 inches thick crust on the surface of soil and must be removed, but leaching of 50% of water applied is definitely too much. We therefore, divided the land in borders 40 feet wide and 264 feet long and tried to apply 2 inches dose with each irrigation and thereby reducing water application to 80 inches and reducing losses to about 24 inches annually.

- This improvement though quantity was large enough but still water applied was excessive. Its effect on soil could not be measured accurately but the yields were definitely higher and trees healthier than the controls. We therefore reduced irrigation frequency. Especially from mid July to mid April, and bringing some more improvement. We still thought a better method was needed and this has been discussed in chapter "Modified Irrigation System for Fruit Trees" next we have finally succeeded in cutting down the water application to about 60 inches annually. Some water still seeps down and carries down salts, but most of salts are leached by annual rains of about 7 inches falling from July to end August in about 6-7 days of down pours.

15. MODIFIED IRRIGATION SYSTEM FOR FRUIT TREES.

The irrigation system in Pakistan is 5,000 years old and 4,350 years ago it reached its earlier peak, which lead to the rise of "The Indus Valley Civilization", also called "Harappan Culture". It was based on diverting the river flood waters in fields which had artificial embankments and about 6 inches water dose was applied every time. When this water evaporated or evapo-transpired another dose was applied. Since land was not precisely leveled, it was divided into a suitable number of small plots and water in each plot was diverted by separate inlets from the main watercourse.

A large number of farmers co-operated, dug large canals and small water courses supplied water to each farmer, who had sub-watercourses laid for each plot of his land, at different ground levels. The river Indus carries 0.6% silt, a large part of which deposits in each field near the inlet and land keeps changing its level. A plot not re-leveled for some years usually has 6 inches water depth on one side and 1 to 2 inches at the inlet. Extra water causes seepage, water logging and low

yields, as irrigation water depth either is very high or very low. Excess water causes low yields, damage to soil structure, hard pan formation and even drain ability is impaired, presently irrigation water from the Government canals is very cheap and in 1994 for an orchard, annual water charges are only Rs.120.00 (US$4.00) per acre. This price of agriculture commodities are 40% of those in USA and under such price structure trickle and sprinkler irrigation are un-economical. We had to device our own method of irrigation suiting flood irrigation but capable of reducing quantity of water applied, seepage, leaching of nutrients and damage to soils.

In 1990 decided to remove banana, as Bunchy Top Virus disease spread in the area. The fields were ready laid in one acre plot 264x165 feet. Deducting for roads and watercourses they were 250x165 feet. These were precisely leveled first. Since new fruit trees were to be planted it was decided to plant trees on ridges 6 feet wide, 10 inches high running from north to south. For high density planting it was decided that spacing of various fruit trees and distances between ridges and furrow will be as under:

Table – VI SHOWING SPACING AT KHESANO FOR VARIOUS FRUIT TREES.

Fruit-tree	Spacing in feet	Ridge width feet	Furrow width feet
Lychee	20x15	6	14
Grape fruit	15x15	6	9
Tahiti lime	15x12	6	9
Guava	13.33x8	6	7.33
Apple	15x8	6	9
Peach	12x8	6	6
Pomegranate	12x6	6	6
Longan	20x15	6	14

The ridges and furrow lines were marked on the ground and quantity of earth needed for the ridge worked out. Using a dumpy level 6x6 inch pits were dug in the bed of proposed furrow at every 15 feet and marked with lime. The depth of pits matched the final level of furrow. The earth then was removed from the bed or furrow and put on the ridge. Ridges initially looked about 13-14 inches high, but shrunk to about 10 inches. Trees were planted on the centre of ridges and water applied in the furrows. Since horizontal permeability of our soils is more than vertical one, water applied in the furrow seeps horizontally in the ridge faster than seeping down. After planting trees the ridges were mulched with all kinds of waste material on the farm to a depth of 6 to 10 inches. Mulch reduced evaporation and also suppressed weed growth under the tree. As a consequence irrigation frequency was reduced from weekly in summer to 10 days; 10 days in

spring and autumn to 15 days and fortnightly in winter, to every 3 weeks. Mulch also reduced soil temperatures from highest May temperatures of 45ºC to 36ºC and increased the lowest winter temperatures from 7ºC to 13ºC. These two limits of temperatures i.e., 13-36ºC are conductive to good tree growth and there was continuous root growth and shoot growth continued 15 days more in autumn and started 10-15 days early in spring.

The rate of growth was almost double and the first crop and the first commercial crop came very early as shown in table below:

Table – VII SHOWING FIRST CROPPING AND THE FIRST COMMERCIAL CROPPING AGE.

Fruit Crops	First cropping age in months	First commercial cropping age in months
Grape fruit	22	34
Lychee	18	30
Tahiti lime	36	48
Gauva	14	26
Grapes	14	26
Peaches	28	40
Pomegranate	22	34
Apple	28	40

These fruit crops were planted in 1991 and have already produced commercial crops. The controls have produced only a few flowers and fruits in 1995.

We also found that dead mulch lying on the top of ridges was mostly dry except that in contact with moist top of the ridge. It is attached by various insects, which invite their predators. There is great bio-activity of insects, bacteria, fungus and earthworms. The 10 inches mulch reduces to about 4 inches in 2 months. Weeds grow profusely in summer in the furrow, which are cut down every second month and put on the ridge and under the trees. On disintegration, mulch provides nutrients mainly nitrogen, phosphates, potash, magnesium, calcium and sulphur in large quantities and traces of copper, zinc, manganese, boron, iron and molybdenum. These are incorporated in the soil and taken up by plants.

Weeds are cut down in March, May, July and September i.e., 4 times a year. Weeds become scanty from November to February. Weeds do emerge under trees and on the ridges. These usually are perennial weeds and are pulled out rather than cut down. A 10 inch thick layer of mulch virtually eliminates weed problem.

There is build up of salts in the ridge, but an average 7.0 inches rainfall annually in July and August washes down the salts.

The advantages of modified irrigation with mulch are:

- Good health of trees, less diseases and less pest attacks.
- Growth rate almost double, what is otherwise.
- First crop earlier and commercial crop soon afterwards.
- Mulch is digested slowly over the year and suppresses weed growth.
- Biological activity under the mulch including earthworms, make soil very porous and incorporate macro and micro nutrients in the soil, readily available for use by plant.
- Mulch reduces summer temperatures and raises winter temperatures thereby promotes root growth, which in turn enhances canopy growth.
- Irrigation water application is reduced almost to 40% as compared to conventional flood irrigation practiced in Sindh.
- Water logging and salinity problems are reduced.
- Root rot problems are eliminated.
- Fertilizer requirement is reduced.
- Application of pesticides and insecticides is reduced.
- Yield is almost doubled as compared to control.
- Problem of compaction of soils and hard pan is reduced.
- Margin of profit is increased.

16. NO-TILL OPERATIONS IN FRUIT TREE ORCHARD

Agriculture Extension had been advocating clean cultivation in fruit orchards. In the Sub-tropical climate weeds grow very fast. The river Indus irrigation system also brings weed seeds. Inter-cultivation 5 times a year beginning with early March, May, July, September and early November was no relief as weeds would become 12 to 20 inches tall in two months. Every second month different weed species had to be tackled in addition to perennial weeds. It was figured out that in this pattern of weed growth, if these are mowed and piled under trees as mulch, at least no weeds will grow under the trees and shallow rooted non-perennial weeds once cut down in the trees inter-spaces, may not re-grow during the season and their root system will decay and leave soil porous.

We started doing it in the whole orchard of 108 acres. The results are out standing. Weeds do grow between tree rows continuously but they are mowed and mulched under the trees. In the inter-space between trees the number of perennial weeds have decreased and only seasonal weeds grow. The soil has become porous not only under the trees but also in the inter-space. The obnoxious weeds have disappeared altogether or reduced and only those easy to cut and mulch have survived. The yields have increased, not only due to notill, but due to many other improvements brought about by us. Notill is advantageous, not only as saving in the cost of ploughing and inter-cultivation, but the soil compaction is reduced, soil health is improved, perennial weeds are reduced and mowed grass used as mulch has improved the yields and health of trees.

17. PRUNING OF MANGO TREES

The mango trees planted at 45x41 feet spacing on 50 acres in 1965-1967 and additional planted at centre of every 4 trees in 1977-79, had started interfering with each other by 1993 and yield in some areas became stagnant and in others started coming down.

We carefully studied the pruning and training practices in Europe, USA, Australia and South Africa and made a detailed plan for pruning. The trees had become too tall and the centre leader or some branches from them or other branches from the trunk had to be cut down, to allow sun-light to fall on at least the 25% of area of the ground. Pruning was started immediately after harvest on 1st July and was continued until end August. All trees to be pruned were marked with red ring at the point of proposed cut and saw cut wounds were painted with zinc-oxide in linseed oil. Some 20% wood was removed. No new growth occurred at the wounds until next spring. Trees were adequately fertilized, with

double the post-harvest dose of N_2. It was observed that northern part of tree which received no light previously was also exposed to light and pruned trees no longer shaded each other at the mid day. The results were outstanding. Next years mango yield was 60% more i.e., from 270 tons to 440 tons though we expected a short fall of 20%. Trees had reached an optimum yield of 8.8 tons acre against 3 tons the average of the country.

In the next year 1994 pruning continued but only 10% wood was removed. The new growth on the branches was grafted with better varieties and process is being continued. The anticipated yield in 1995 was more than 10 tons per acre or more than 500 tons from 50 acres.

The wood removed from the trees has been utilized for construction of doors and windows and other furniture for Institute of Organic and Sustainable Horticulture and Agriculture Research unusable thin wood was disposed off in the market.

Pruning, training and thinning program has been extended to all other trees in the orchard. The other farmers in the area have not adopted this method, though they are convinced about high yields but they think it is due to other cultural practices we have adopted.

18. COMPOSTING SAW DUST.

The wood from mango orchard was used for making doors, windows, furniture fittings and etc. The residues were, bark, saw dust, wood chippings and small pieces of wood. The first two could be composed easily and this was done by adding dolomite, urea, potassium sulphate, SSP and small doses of sulphate of copper, iron, zinc and manganese, sodium molybodate and boric acid, over a period of some two years, as saw dust became available. The composted material then was mixed with river sand in the ratio of 1:1 by volume and used as potting mixture for nursery plants. Composted saw dust has very low pH and river sand has pH of about 7.8 the mixture formed good potting material with no problems of germination.

19. ELIMINATING USE OF HERBICIDES ON THE FARM

We had used herbicides on the farm some years ago and our conclusion was that they promote hard to kill and perennial weeds by eliminating annual weeds. We therefore concentrated on alternative methods. In our case irrigation water from the river Indus brings new weed seeds every time water is applied. Inter-

cultivating is no solution and at the best it is preparation of a good seed bed for new weeds. Allowing them to grow has advantage that new weeds do not grow under their shade. We finally found a solution that if weeds are allowed to grow between trees rows and are cut down and piled under the trees canopy, weeds do not grow under the pile or mulch.

This method has been practiced in the past 6 years on newly planted fruit trees namely, lychee, longan, Tahiti lime, grape fruit, grapes, guava, mango, peach, plum, pear, apple, persimmon and pomegranate.

It has been noted that growth rate is almost double or more as compared to controls i.e., when weeds are removed by hoe. First fruiting is also earlier and first commercial crop is harvested in the year three or four. The trees are also healthier and yields are more.

The grass pile gets digested in 2-3 months and it is renewed by another pile of weeds growing between the tree rows. Weeds need cutting down about 5 times a year. The organic matter pile under the whole canopy acting as mulch is attached by insects, soil fauna and earthworms, making soil healthy, rich and porous and promoting tree growth. Mulch also lowers soil temperatures in summer, raises them in winter and thus promotes root growth.

Since adopting this method, we have cut down on pesticides and at the most one annual spray before flowering is needed for high yields. The fertilizer requirement is also reduced, because the weeds occupying area between the trees contain NPK and micro-nutrients.

Since the labor wages are low, the method is cheaper than inter-cultivation. Lately we have introduced Hyter chopper/mower, which cuts down weeds between tree rows and these are collected by labor for piling under the trees.

20. UREA AS WETTING AGENT AND GROWTH REGULATOR

While spraying micronutrients and other chemicals to trees we added urea to the mixture, to act as wetting agent and the advantages derived are as under:

- Micronutrient absorption is improved.
- Urea at 2% in November and December improved fruit quality TSS and pulp seed ratio in Z. mauritiana. June is proper time for Z. jujube.

- Spraying Z. jujube and Z. mauritiana with 6% urea in September increased shoot size, fruit size and weight and yield. Same results were obtained with ZX. Jujube when sprayed in March.

- Urea at 1 to 2% applied to lychee before flowering increased flowering and fruit set.

- Urea at 25% can defoliate guava and induce new flowering.

- Urea sprays can bring crop early and shorten harvest time in guava.

- Urea spray at 1 to 2% in summer, three times at 15 days interval or at 4% in winter during flowering stage can increase yield by 25 to 50% in guava.

- After defoliation 3 sprays with urea at 15 days interval can also increase yield of guava.

- Urea when applied to mango can delay harvest date. Now we invariably use urea on all fruit crops for enhancing flowering, fruit retention increasing its size and weight and timing of harvest.

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21. UREA OF INORGANIC FUNGICIDES IN PLACE OF ORGANIC ONES.

A number of fungal diseases attack subtropical fruits. For example the fungal diseases of the popular fruit crops are:

Mango: Anthracnose, stem end rot, bacterial black spot.

Guava: Blossom end rot, fruit canker, grey blight, fruit spot, and Anthracnose.

Citrus: Brown rot, Alternaria, Melanose, Phytophthore, and Black spot.

Grapes: Black spot, downy mildew, Powdery mildew.

Lychee: Anthracnose algae spot, trunk canker, armillamari and root rot.

Longan: Powdery mildew, witches broom, and black mildew.

Pomegranate: Fruit rot, bacterial leaf spot and canker.

Persimmon: Anthracnose, leaf trunk canker.

Zyzyphus Mauritiana/ Z. jujube: Fruit rot, bacterial leaf spot and sooty mold.

Our soils having high pH are deficient in copper, zinc, manganese and iron and these ingredients are needed and applied regularly. Applied in form of sulphates especially copper sulphate, this material can act as fungicide and also will help in control of fungal diseases. The program was started in 1987 and most of fungal diseases have been reduced to a degree where no economic damage occurs. Leaf analysis is done annually but light doses of these metallic sulphates are applied from September onwards to harvest aimed primarily at disease control but keeping in view that nutrients applied are also within limits. The chemicals play their role in two ways; they supply micro-nutrients and thereby increase yield and they also control diseases and thereby control fruit fall, fruit tarnishing and damage and thereby also increase yields.

We are not able to assess the exact, benefit, but with mulching, regulating macro-nutrients and micro-nutrients, as well as disease control, we have tripled the yield of mango, from about 3.0 tons per acre in 1987 to 8.8 tons per acre in 1994 and 9.5 tons in 1995.

22. BIO-GAS FROM AGRICULTURAL WASTES

The first bio-gas plant in Pakistan was built in 1959 by M.H. Panhwar at Agricultural Engineering Workshop Tando Jam, 4 miles away from our farm. It is still working because of a number of features and safety measures. All kinds of agriculture wastes, FYM, poultry droppings, waste paper, cardboard had been digested experimentally. 1982 we wanted gas on the farm for lighting and cooking of crew employed for harvesting of mango and banana.

It was also the time when under USAID large number of bio-gas units were being installed, though the design and construction was so defective that many thousand plants installed by them had failed to work.

We installed a bio-gas plant in an abandoned centrifugal pump tube-well pit, 16x16x22 feet deep and put 4 floating gas drums 7x7x4 feet on it. We used farm

waste material and buffalo manure brought from neighboring village. It could run a small gas engine, when there was no other use for it, but it was primarily used for cooking. It was abandoned after 3 years because of following findings:

- It was cheaper to burn waste wood and twigs from the farm for cooking rather than gas produced from bio-degrade farm waste material.

- The satisfactory working of the plants depends upon ambient temperature. In winter the gas production was 30% that of the summer.

- The gas production was also governed by pH. All efforts to maintain the pH at optimum levels needed daily attention of the manager who was a technical person.

- In winter gas production could be increased by heating liquid in the digester but 50% of gas generated was burnt and only 50% was available for cooking.

- C:N ratio was difficult to maintain and could only be kept optimum by addition of urea.

- The slurry produced could not be handled easily and economically.

It was concluded that bio-gas plant on a small scale was not worth while and therefore instead of putting bio-degradable agricultural waste in the digester, we decided to use it as mulch, which was far better a proposition.

23. CONCLUSION AND CODE OF PRACTICE FOR SUSTAINABLE AGRICULTURE

The above discussions show the various methods devised by us to raise fruit crops economically with minimum tillage reducing use of tractors, synthetic fertilizers, and plant protection chemicals, making optimum use of irrigation water and protecting soil with most desirable soil amendments and nutrient supply. In the course of trials we also found that healthy soil produced healthy trees which faced diseases without too much reduction in yield. We therefore laid down rules or code for our farm managers, supervisors and foremen and this is being strictly adhered to:

The basis of this program are:

Little or no tillage.

After making ridges for trees and furrows for irrigation channels, no tillage implements are allowed to enter the farm and instead of inter-cultivation for weed control, following methods are permitted:

Control and addition of organic matter to soil.

- Allowing natural annual and perennial grass to grow profusely within the furrows, cutting it periodically and putting it as much under the trees ridges on which they are planted.

- Indirect irrigation of trees, through furrows so that water seeps horizontally into the tree root zone, and use of water in the furrow to grow annual weeds, the roots of which decompose after grass is cut and make soil porous.

- To protect plant trunk from moist mulch material by wrapping discarded X-Ray films round the trunk of tree and stapling it.

- To maintain mulch layer in a diameter of about 6 feet or even the whole ridge if enough mulch material is available and try to maintain it year around.

- To eliminate rodents sheltering under mulch, maintain high population of owls, by providing bird shelters on the wind break trees.

Soil amendments for its productivity.

- The weeds in the furrows will be cut down and thrown under the trees and on the ridges every two months and pile 6” to 10” high maintain except in the rainy months of July August when it should be 4” thick, so that it may not compact.

- As far as possible mulch layer should spread on the whole ridge as roots extended horizontally from one tree to another.

- Beside nutrient supply from weeds and other natural grass mulches, if plants show nutrient deficiency signs, crop residue composts, oil cake, rice bran, fish and bone meal, composed farm yard manure and poultry droppings and grass and wood ashes may be added.

- In case of micronutrient deficiencies sprays of mineral compound solutions in water in proper proportions may be applied taking care, that copper compounds are not mixed with iron compounds and iron compounds are not mixed with boron. Copper compounds may also be used as fungicides.

- Re-cycled paper, sugar-cane bagasse may be used as mulch, if no other material is available.

Plant protection measures.

- Health of soil and plants may be improved so that the latter are able to face disease and paste attacks without affecting yield too much.

- Companion crops, repellent plants and plants attracting natural enemies may be planted. For example okra or lady's finger may be planted within mango groves so that the mildew on okra a predator of mango and other crop mildews, reduces populations on the latter.

- Use of traps, predator birds, nets and use of noise devices to repeal harmful birds.

- Use of natural enemies or predators.

- Use of adhesive traps on trunks of trees to stop climbing of crawling insects.

- Soap free of fungicides and detergents.

- Khairpur lake natural soda.

- Natural mineral extracted from neem, kharpat and etc.

- Machine oil emulsion.

- If pests, diseases and insects still persist use of chemical insecticides and organic fungicides once a year may be allowed.

Compost inoculants.

- Microbial inoculants may be used for making composts on the farm.

- Compost material having higher than C:N=30:1 may be added urea, ammonium nitrate, FYM or any other natural source of nitrogen.

Animal excrete.

- Any excrement to be used on the farm as fertilizer or compost may be composted before use, to kill parasites.

ABOUT THE AUTHORS

M.H. Panhwar received bachelor's degree in mechanical and electrical engineering from NED Engineering College (Now University) 1949 and master's degree in agricultural engineering from University of Wisconsin 1953. He received three years training in agriculture and earth moving machinery with M/s. International Harvester Co., in USA and from 1953 to 1969 operated a fleet of 600 bulldozers and installed 3000 tube-wells for farmers in Sindh and Baluchistan Provinces of Pakistan. He wrote four books on 'Ground Water in Sindh' in 1962, 1963 and 1964 and the second edition of the last came in 1969. For the past 25 years he is Managing Director of an engineering consulting company working on irrigation, drainage and salinity control in Sindh.

His hobbies besides fruit culture include research into history, archaeology and anthropology of Sindh and introducing new fruits, nuts and industrial crops. His major books on Sindh are: 'Source Material on Sindh', 'Chronological Dictionary of Sindh', 'Social History of Sindh', 'Historical Atlas of Sindh' and 'Five Thousands Years History of Irrigation in Sindh', in addition to about 100 articles published in two research journals 'Sindh Quarterly' and 'Sindhological Studies'. His personal collection has 11,000 rare books and 3,000 historical maps on Sindh. In 1992, the President of Pakistan gave him highest civil award 'Sitara-e-Imtiaz' (Star of Excellence), in engineering and agriculture.

Mrs. Farzana Hussain Panhwar got master degree from University of Karachi in Bio-chemistry in 1981. She has worked on soil chemistry, macro and micro-nutrients, composts, organic fertilizers and growth regulators as applied to fruit crops and post-harvest technology of subtropical fruits. She has also published a number of articles on animal, poultry and prawn feed, raising of shrimps and rabbits, plants of desert areas of Sindh, bio-gas from agricultural wastes and genetic property.

Since 1982 both have been working together on application of organic methods in fruit culture, introducing new fruit nuts and industrial crops and use of latest technologies on their 43 hectares farm. Among the new fruits introduced commercially in the past 10 years are; lychee, longan, grape fruit, guava, grapes and low chill apples, peaches and pomegranates imported from abroad. Their yields match those of advanced farmers in developed countries. They have under trails low chill plums, pears, and persimmons, almonds, figs, jojoba, jatropha, avocado, simaruba glaca, cashew, macadamia and etc. They also propagate all the above plants for their own use. They are frequest world travelers and have visited many countries in search of new varieties of fruits. They have collected

10,000 books and bulletins on above fruit success due to sustainable methods, but when diseases reach economic injury level they get compelled to use insecticides and pesticides only occasionally.

They have jointly published a number of articles on new fruits, nuts and industrial crops. The Government of Sindh has recently decided to publish some books on fruit crops, authored by both of them as listed as under, for use as guides for agriculture extension workers, researchers, industry and farmers.

List of hand books on various fruits, nuts and industrial crops by M.H. Panhwar and Mrs. Farzana Panhwar, being published by the Government of Sindh.

1. Chinese and Indian Jujube (90 pages).
2. Guava (96 pages).
3. Lychee (140 pages).
4. Longan (60 pages).
5. Pomegranate (75 pages).
6. Fig (50 pages).
7. Persimmon (Chinese) for subtropics (85 pages).
8. Almond for subtropics (50 pages).
9. Jojoba (55 pages).
10. Mango (220 pages).
11. New fruits, nuts and industrial crops for Southern Pakistan (228 pages).
12. Grapes for subtropics (150 pages).
13. Low chill peaches, nectarines and plums for subtropics (150 pages).
14. Low chill pears for subtropics (96 pages).
15. Citrus (148 pages).
16. Apple for subtropics (129 pages).
17. Date (80 pages).
18. Roses (70 pages).