The Third Dr. R. V. Tamhane Memorial Lecture

Soil and Water Management—The Key to Production in Rainfed Agriculture of Semi-Arid Tropics*

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The Semi-Arid Tropics of the world are characterised by short wet period and long dry periods. The evapotranspiration demand of the climate far exceeds the precipitation for most part of the year. According to Troll (1966), the areas characterised by 2-4½ wet months (P>ET) and 10 to 7½ dry months are classified as dry semi-arid tropics whereas 4-7 wet months and 8-5 dry months are considered humid semi-arid tropics. It is the dry semi-arid tropics where the problem of crop production is most serious. But interestingly enough nearly 600 million people of 48 countries live in the semi-arid tropics of the world and most of them live in Semi-Arid Tropical (SAT) belt of India. It is not only human beings who are too large for the meagre food and water resources of the Semi-Arid Tropics but also the animal population is far too large for the capacity of the region to support.

Strangely enough, in this region the percentage cultivated area of the geographical area is also very high. In some of SAT districts in India 70 to 90 per cent of the geographical area is cultivated. As the pressure of population builds up, more marginal lands are brought under cultivation, thus increasing the problem of soil erosion and adding to the instability of production causing permanent damage to environments. The SAT produce about 50% of the world's sorghum, 40% millet, 90% chick pea 95% pigeon pea and 60% groundnut. India is the largest producer of these crops. Though it has only 9% of the area of SAT, it maintains a human population of 260 millions in this region.

More than 39% of operational holdings in SAT India are less than 0.4 hectare and 54% less than one hectare. Only 3% have more than 10 hectares. Thus in SAT India majority of the farm holdings are small and fragmented. Large-farm technology which is prevalent in developed countries is not applicable to Indian situation.

The yields of crops are low and fluctuate from year to year. The occurrence of droughts is very common and devastating. The drought prone areas of India and Sahelian region wherein untold misery by human beings and animals was felt in recent years, are grim reminders of inadequacy of technology and incapacity of human beings to tackle this problem. The development of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the All India Coordinated Dry Land Agriculture Research represent the international and national efforts to develop a suitable technology for these rainfed regions of the semi-arid tropics.

In India, in the early forties, a research project on dry farming with five centres at Rohtak (alluvial soil), Sholapur (deep black soil), Hagari (black soil), Raichur (black soil) and Bijapur (black soil) was in operation for a few years. Based on the results of these projects, dry farming

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practices which became popular under the names such as Bombay dry farming, Madras dry farming, Hyderabad dry farming or Rohtak dry farming practices were developed. These practices emphasised soil and water conservation as a basic necessity to dry land production. However, the marginal return of 15-20% over the base yield of 200-400 kg/ha did not impress the farmers. Thereafter the dry land research receded in the background and research on irrigated farming caught the attention. However, after independence, particularly in the early fifties, soil conservation development programmes became more popular with the Governments and later on it became synonymous with contour bunding. The impact of this programme also did not become as spectacular as expected for the simple reason that biological system which should have formed an integral part of the soil conservation was neglected. It is no wonder that the soil and water conservation programmes failed to produce the expected results. This is an interesting lesson to remember.

Then came the era of coordinated project on crops and agronomic trials. In 1966 after the reorganisation of the ICAR, soil and water management research was also organised on all-India basis. The research on dry land agriculture was given a high priority with an appropriate financial support. This opened a new chapter in agricultural research in India as it was realised that the people of the dry land areas had waited too long and unless a viable technology was evolved for this situation, the agricultural progress would remain lopsided and stability in agricultural production a nightmare.

It was soon realised that for the dry areas with low rainfall, particularly arid and semi-arid tropical zones, a massive effort was needed both in research and development aspects as the people of these regions were being bypassed by the green revolution, which benefitted the irrigated and favourable rainfall areas. This led to the formulation of the All India Coordinated Dry Land Research Project and Pilot Project on Dry Land Agriculture. An international effort resulted in the establishment of ICRISAT which represents both the soil and water conservation and crop improvement researches. The whole theme of ICRISAT as well as dry land agriculture research revolves around water, which is the most limiting factor in seasonally dry semi-arid regions of the world, particularly India. The whole story revolves round soil-water, crop and man. Let us discuss the various aspects of the problem. I am taking India as an example for illustration.

SOIL RESOURCES AND PROBLEMS

The soils of the semi-arid tropics are predominantly black soils (Vertisols), and red soils (Alfisols) and some alluvial soils (Inceptisols) and laterite soils (Oxisols) also occur.

At ICRISAT site fortunately both the black soil and the red soil occur, which provide a good setting for all research on soil, water and crop management.

Although in India an extensive research on the genesis of red and black soils, which often occur side by side, has been done but, still the knowledge about these soils is inadequate. A classical work on the genesis and characteristics of these soils was reported by A. D. Desai (1943). Tamhane and Narasingha Rao (1956) and Biswas & associates (Biswas and Gawande 1962; Biswas *et al.* 1966) have continued these studies and added to our knowledge on the subject, but still there are gaps in our understanding of these soils. Why under the same situation in one field the soil becomes red and in another black, is very intriguing. Even at ICRISAT site, the dividing line between the two soils is very sharp and it appears as if it were man-made.

Genesis of Red and Black Soils

Rengasamy (1975) reviewing the red and black soils association in SAT India concluded that most of the investigators have failed to relate all the factors *viz.*, the geomorphic positions, geomorphic history, physical and chemical nature of the parent material and mineral components of the soil. He further concluded that most of the distinctive features of these two types of soils are controlled by their clay mineral composition. In general black soils have dominance of smectites, while red soils have kaolinites. The formation of clay minerals is controlled by the activities of monomers of Si, Al, Fe, the cationic composition and pH of the weathering solutions. Hydrodynamics plays the most important role. While free drainage and oxidation leads to formation of red soils, the reverse of it results in genesis of black soils. Evidently one has to look into the details of geomorphology and geomorphic history besides parent material for understanding the complexity of genesis of red and black soils in juxtaposition. It also happens that black soil may be on the high elevation than the red soil, though generally reverse is the case.

Red Soils

The red soils are usually developed from ancient granite or gneisses. The soils are highly weathered and leached and thus low in bases, phosphorus, micronutrients particularly zinc, organic matter and nitrogen. pH ranges from 5.5 to 6.8. The clay is of kaolinite type. Soil fertility status is rather poor. The water holding capacity of the soil is much lower than of the black soil generally by a factor of 2-3. The soil texture on the surface is gravelly to sandy loam and clay content increases in B horizon. The soil depth varies but generally shallow to medium deep. Because of low moisture holding capacity and shallow depths, the amount of moisture in the soil to support a crop is rather very low, hence without supplemental irrigation, such soils are not capable of supporting more than one crop. The red soils generally occur on slopes and are highly erosive. Sheet erosion is very common. Crusting is a characteristic feature. When dry they are difficult to till. When wet they become erodible.

Black Soils

The black soils are potentially more productive than the red soils, but they are most difficult to manage. They have higher cation exchange capacity, higher moisture retention capacity, higher organic matter and nitrogen, higher base saturation with the exchange complex dominated by Ca. The clay is of montmorillonite type and the amount of clay is very high (40—60%). These soils may be shallow, medium or deep. Thus the available moisture status varies with the depth of soil profile. The black soils are hard in the dry season, sticky and plastic in the wet season. Erosion is a serious problem, particularly when kept fallow. They are called self-mulching soils which develop large cracks when dry and slickensides on rewetting. About 64 million hectares of black soils are found in India. They also occur in Niger, Chad, Dahomey, Senegal, Upper Volta and Sudan.

Alluvial Soils

The alluvial soils are also present in SAT to a considerable extent. Their properties are too well known to need any recounting here.

SOIL AND WATER MANAGEMENT IN THE SEMI-ARID TROPICS

In recognition of the fact that most of the cultivated area in SAT India is under dry land agriculture and water is the major constraint for crops, the main goal of ICRISAT research is to evolve land and water management techniques for increasing and stabilising agricultural production. Special emphasis is laid on collection, storage, recycling and efficient utilisation of runoff water on a watershed basis. The first problem is to increase the infiltration of rain in the soil so as to store the moisture in the soil itself. Timely tillage, mulching, soil conservation practices to allow more time for water to infiltrate in the soil are very important considerations for this purpose. The control of soil erosion and water loss are facets of the same problem.

The second problem is to prevent the loss of water from the soil ensuring its most efficient use by crops. The weed control and soil and crop management are the key factors in this case. The third problem is to harvest the excess water which would otherwise runoff and go as waste. The fourth problem is to recycle or use runoff water for efficient cropping by giving life saving irrigation. This is also called runoff farming.

Soil Management for Storing Rain Water

(i) *Infiltration rate and moisture storage :* In black soils, the infiltration rate in the beginning of the monsoon is high because of the cracks. As soon as the cracks fill up and the soil swells, the infiltration rate decreases sharply. However, the management of the soil like interculture and presence of vegetative cover are the other important factors affecting the infiltration rate. Towards the end of monsoon season again the black soil which has been under crop cover with ridge and furrow system shows greater infiltration than its counterpart which was fallow during the monsoon. Kampen *et al.* (1976) reported that on black soils the steady state infiltration rate in monsoon fallowed plots was about 1 mm/hr as compared to 6 mm/hr on cropped land under ridge and furrow system while the flat cropped land was intermediate between the two extremes.

In the black soils of Bellary, Krishnamoorthy (1976) reported that application of gypsum to reduce the exchangeable sodium percentage by 2-3% increased the water intake rate from 0.8 to 10 mm/hr. In the same soils vertical mulching with crop residues at regular intervals proved very effective for increasing the rate of intake of water into the soil. The effectiveness of organic mulching with crop residues in increasing water infiltration into the soil and reducing the erosion by de-accelerating the rain drops and lowering their energy to cause erosion is well established. The only problem is the availability of the mulches and the competition with the cattle for those organic residues which are the main source of feed for them. The technology of crop residue management *in situ* has not yet received adequate attention. How far it can be practicable is a matter for investigation.

In the black soils of Sholapur which have less permeable subsoil, deep ploughing is considered essential for increasing infiltration, improving soil moisture storage and removing weeds which are serious competitors of crops for moisture and nutrients.

ICRISAT experience shows that ridge and furrow system is more effective in increasing infiltration than the conventional contour bunding. On the red soils the graded ridges 150 cm apart increased the infiltration by 25% as compared to the flat.

The red soils, unlike the black soils, have low infiltration for the first monsoon showers of rain but soon after wetting, they improve in this ability. However, because of low water holding capacity these soils have a lower capacity for sustaining more than one crop a year.

(ii) *Runoff:* The runoff loss of water in a given situation is more from red soils than from black soils ; thus the potential for water harvesting and building of tanks for irrigation in red soil area may be more. The only problem in such situations is prevention of loss of water through percolation. Experiments involving treatment with sodium carbonate as to exchange calcium with sodium in the exchange complex to a certain extent are quite promising. Virmani *et al.* (1976) after analysing 70 years data reported that at Hyderabad while from shallow red soils the median value of runoff water is 134 mm, from the medium to deep black soils it is hardly 39 mm, thus there is a greater possibility of runoff water collection on red soils than on black soils. This indicates the possibility of runoff farming in the red soils, experimentation involving construction of tanks should be confined to those areas where rainfall patterns and soil conditions are such that high payoff can be expected.

(iii) *Crust formation :* The crust formation is quite a serious factor in red soils. Crop residues when incorporated in the soil or organic mulches on the soil reduce the crusting considerably. Krishnamoorthy (1976) reports that seeding on the ridges and using tooth harrow within 1 or 2 days after seeding are quite effective against crust. However, if the crust is formed after 3 or 4 days when the seedlings are just emerging, then it becomes the most difficult problem. Even use of gypsum has been found effective in some situations. Growing of crops like castor and pigeon pea which produce seedlings with greater ability to pierce the crust is helpful. But crops like pearl millet, finger millet and also sorghum face great problem. Mulching techniques to keep the soil in a friable condition is very helpful in getting over the ill effects of crusting.

(iv) *Water storage capacity of the soil.* The water storage capacity of the soil profile depends upon a number of factors but generally the black soils have greater storage capacity than the red soil of the comparable depth. Considerable laboratory data on the moisture storage capacity of soils exist, but very little information is available about the balance sheet of rain water in black and red soils and much less on the efficiency of this moisture in crop production. When the soil profile is shallow and soil texture light, very little improvement on the moisture storage is possible, except through very expensive treatment which make it highly uneconomical. In the black soils with hard impermeable layer, chiselling or deep ploughing becomes effective.

(v) *Rainfall data and moisture data for crop planning :* Using 70 years rainfall data of Hyderabad and the computer analysis Virmani *et al.* (1976) have determined the probability of successful cropping in shallow red soils, deep red and medium black soils and deep black soils of 50, 150, 300 mm available water storage capacity, respectively. Their conclusion is that for the shallow red soils, the successful cropping season is 17 weeks, for medium soils 21 weeks and deep soils 25 weeks in *kharif* season. The effective crops depending upon the variety and management are given in table 1.

The duration of the variety of the crop, time of sowing, method of planting, and soil and water conservation techniques are important factors determining the system of cropping. Virmani *et al.* (1976) have made a number of such projection and calculated the probability of success of these crops. They concluded that on all soil types, a 120-140 day base crop continued with a short duration inter-crop is likely to confront the smallest probability of adverse weather. In the red soils where the inter-seasonal probability of drought is higher, an indeterminate crop or crops with long spread flowering, *viz.*, groundnut, castor, may suit better. In the deep soil regions of Sholapur with relatively undependable rainfall, *kharif* fallowing followed by *rabi* cropping may be the best practice. However, in the shallow and medium black soil areas of Akola and Hyderabad, which have fairly dependable rainfall, *kharif* cropping is very satisfactory. In the other areas with deep black soils and dependable rainfall, *kharif* cropping followed by sequential cropping in the *rabi* season is quite efficient. It hardly needs be emphasised that soil and climate are the fixed parameters and crop and cropping systems can be tailored to fit in a particular niche. Simulation models, based on rainfall distribution, probability analysis and soil moisture storage data, can be made for various studies to determine the efficient cropping systems.

(vi) *Soil conservation methods :* Contour bunding which is the traditional method of soil conservation for black as well as red soil is open to question. Under many situations, particularly in deep black soils, there is an overwhelming evidence that the contour bunds which in practice are the field bunds, result in inundation of a part of the land thus adversely affecting the crops. Kampen *et al.* (1976) have collected some evidence on the reduction in yield by this inundation. Krishnamoorthy

TABLE 1

Suitable efficient crops for soils of different moisture storage capacity in Hyderabad (rainfall 750 mm)

Soil	Amount of available water held in soil profile (mm)	Most effective crops
Shallow red	50	Grasses and foragės, castor, pearl millet
Deep red*	150	Pigeon pea, castor, Setaria (Italian millet) Sorghum (medium duration), groundnut
Medium black*	150	As in the case of deep red soil, groundnut is successful if the surface soil has light texture
Deep black**	300 & above	Pigeon pea, maize, sorghum (preferably more than 120 day variety)

*Great scope for inter-cropping

**Great scope for double cropping, relay cropping and sequence cropping

(1976) has convincing data on the same subject from Bellary. The experience at Soil Conservation Research Centre, Ibrahim Patnam, Hyderabad, provides evidence of unsuitability of contour bunding even in red soils. Preliminary observations at ICRISAT show that broad based beds or ridges offer greater efficiency for moisture conservation, and greater elasticity for efficient crop management in both the red and black soils. More intensive research under different benchmark situations is needed to provide an unequivocal evidence for the most efficient soil conservation system for both these soils. The African experience is that the tie-ridging is most effective for moisture conservation and increasing the efficiency of rain water in red soils.

Not only for soil and water conservation but also for water recycling or extending the cropping season and providing life-saving irrigation to the crops in the monsoon as well as post-monsoon seasons, the broad ridge system may offer even greater advantage. However, we have to learn more about the best practice. The time honoured tradition of fallowing is also questionable as it leads to high loss of soil and water. ICRISAT scientists observed that the fallowed watershed during September gave 5 times more runoff than the cropped watershed. During the September 1974 storms the erosion in monsoon fallow watershed was observed to be 12 to 23 times higher than in the cropped watersheds. The rainfall use efficiency of the monsoon fallowed system is hardly 30% of the other system in black soils. But still in many black soil regions *rabi* cropping is the prevalent system. It is partly to cover the risk involved in monsoon cropping in this region due to lack of satisfactory technology and partly due to the greater risk involved in the monsoon cropping in this region. The whole question needs a fresh look.

Optimising Crop Production from Conserved Moisture

It is not enough to store the moisture in the soil but also equally important is to produce more crop per unit moisture thus stored. It requires a selection of suitable crop, its variety, efficient cropping system, best time of sowing, method of planting, fertilizer application, weed control, etc. The efficient plant type is essential for the best utilisation of the environment. The sorghum hybrids generally have proved to be more efficient utilisers of stored moisture than the local varieties in black soils. On the deep black soils of ICRISAT, double cropping is highly efficient even without any irrigation, whereas on the red soil, double cropping is possible with supplemental life-saving irrigation with the water harvested from the same watershed during monsoons. The inter-cropping is not only a device for risk covering in rainfed agriculture of semi-arid tropics, but also ensures greater efficiency in utilisation of the moisture or exploiting the environment. Inter-cropping has not received so much attention from scientists in SAT areas for rainfed farming condition as it deserves. Let us realise that sole-cropping system is not the ideal one for these areas of uncertain moisture and full of risks.

The dry sowing of crops in black soils generally results in more efficient utilisation of the environment. Advancing the date of sowing of *jowar* (*Andropogon sorghum*) by about a month is more efficient in black soils of Bellary and Bijapur than the traditional sowing dates. It results not only in better pest management but also in obtaining greater efficiency per unit water stored in the soil. Likewise, inter-crop of (i) pigeon pea + sorghum, (ii) pigeon pea + pearl millet, (*iii*) pigeon pea + *Setaria* are more efficient than the sole crops alone in exploiting the soil environment.

There are a number of alternatives for cropping under any situation of black or red soil but the use of these alternatives is determined not only by the technological considerations but by the economic advantages as well. The All India Coordinated Dry Land Agricultural Research Project is developing such alternatives for different agro-climatic and soil situations, whereas the ICRISAT scientists are trying to develop the concepts which may have applicability across the SAT belt. The weed control and soil fertility management are other facets of soil and crop management systems. The use of fertilizers, particularly of N, P and Zn is invariably found beneficial for increasing crop production in the SAT region. But the important aspect is the economics of the whole system.

Harvesting and Storage of Excess Water for Efficient Utilisation

In the previous pages, the question of harvesting the runoff water has been discussed. Nevertheless, it cannot be overemphasised that the most critical point is the efficient use of water. The watershed concept which is being developed by ICRISAT scientists has certain merit but still one has to go a long way to come to a final conclusion about the most efficient and economical tank system, irrigation delivery system and cropping system combination. The traditional tank irrigation system was primarily confined to rice cultivation, which in the context of today's situation is not tenable. If a different system is to be used it requires further studies of its economics. It also calls for a certain degree of group action. It necessitates introduction of most efficient delivery system. There are indications at the ICRISAT site that graded ridges and furrow system may be efficient not only for soil and water conservation but also for reuse and redistribution of runoff water collected from the watersheds. Should the tanks be deep, shallow or medium deep? Efforts are being made to evolve a system which permits the most efficient use of water stored in the soil and the water harvested as runoff.

In the black soils because of the higher water holding capacity of the soil itself the scope for use of runoff water is rather low. Most of the harvested water is required for *rabi* or dry season cropping for use at the most critical stages of crop growth.

Reuse of Water for Life-Saving Irrigation

It has to be recognised that the runoff water harvested from the land in SAT areas can not be considered for development of conventional irrigated farming. Its primary use should be for stabilising production by providing minimal irrigation at the most crucial stage of the crop growth.

There are two disturbing factors in rainfed agriculture of the SAT regions. One is inadequate moisture at sowing time, which may lead to poor germination, poor stand of crop and ultimately low yield. The other is the prolonged drought which affects the crop adversely, particularly if it persists even during the crucial stages such as flowering, grain filling, *etc.*

On black soils where *rabi* cropping is commonly practised with the conserved moisture, the first problem is mainly the soil management, tillage and sowing at the proper depth using proper seed rate and satisfactory geometry of crops. The second problem is to make the crop a success and the solution to this problem lies in life-saving irrigation. The soil moisture data are valuable guides in both the cases.

In red soils supplementary irrigation during monsoon season is necessary to tide over the inclement weather situation and during *rabi* season to extend the season for sequential cropping or relay cropping.

Some results obtained at ICRISAT on red soils show that 5 cm of water applied at the most crucial stage increased the yield of sorghum, pearl millet, maize and sunflower by 106, 59, 95 and 32 per cent, respectively. Similar results have also been observed in the All India Coordinated Dry Land Agricultural Research Project. Such studies need be intensified so as to develop concepts for making the best use of harvested water.

Integrated Use of Technology

For rainfed farming, the use of integrated technology for crop production is more significant than even for irrigated farming. For the maximum pay-off, it is essential to ensure the interaction of Land and Soil management x Crop management x Water management. In a red soil a local variety of sorghum with conventional land, soil and crop management practices and 50 cart loads of farmyard manure (local practice) produced 1,190 kg grain sorghum/ha, whereas the improved variety (CSH-5) with improved land, soil and crop management practices and use of fertiliser produced 3,480 kg/ha. The improved land, soil and crop management increased the yield of local variety by 457 kg, but it increased by 1,090 kg in the case of CSH-5. These results clearly show the effect of integrated technology for getting the maximum pay-off under rainfed farming in the semi-arid tropics.

CONCLUSION

For the development of efficient system of rainfed agriculture in the semi-arid tropics, an understanding of the new equations of climatic elements, soil environment, crops and cropping systems and their management is required. The black and the red soils which are representative and dominant soils of the semi-arid tropics have not received as much attention as they deserved. The study of genesis and manage ment of the red and black soils, for reducing erosion and loss of water, and improving their capability to enhance the efficiency of rainwater and crop yields, is essential.

It seems that a new technology involving interaction of soil x water x crop is developing in which the soil scientists could not rest looking at only one aspect as it is only the integration of all these aspects which can lead to a sound technology.

On this day I am reminded of Dr. R. V. Tamhane, who did a good work on the genesis of red and black soils of India and made a useful contribution to the soil survey and soil conservation research and development in the country.

I feel that the only way to remember him is to develop techniques for the most efficient system of management and utilisation of red and black soils. Unless the soil scientists look at climate-soil-water, crop as one system they cannot develop the most efficient system for crop production in the SAT regions.

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About the Lecture

Dr. R. V. Tamhane Memorial Lecture was instituted in 1974 by the Indian Society of Soil Science out of a donation of Rs. 12,000/- received from Dr. Tamhane Memorial Committee in memory of late Dr. R. V. Tamhane who was snatched away suddenly on January 23, 1973 from this world by the cruel hands of destiny.

After a short period of service in the Department of Agriculture of the then Bombay Province, Dr. Tamhane joined the Indian Agricultural Research Institute in 1945 as Assistant Soil Survey Officer and in 1958 he became the Head of the Division of Soil Science and Agricultural Chemistry. In 1961, he joined as Adviser (Soil Conservation) in the Ministry of Food, Agriculture Community Development and Cooperation of the Government of India, and held this position till his retirement in 1970. Soon after, he was invited by the Reserve Bank of India to take over the responsibilities of the Director (Technical), Agricultural Refinance Corporation at its Bombay office.

His main scientific contributions are in the field of soil survey, soil genesis, soil conservation and soil testing. The credit of organising the Soil Testing Service and a chain of Soil Testing Laboratories in the different states of the country goes to him. On several occasions he was assigned important responsibilities of representing India at many national and international conferences.

He had a fairly long association with the Indian Society of Soil Science as a Member, Joint Secretary, Secretary and finally as the President. Whoever had the occasion to come in contact with him, whatever be his walk of life would remember his sweet, straightforward and cordial nature. All his colleagues found in him the quality of an able administrator, a noble heart and a true sportsman in every sense.

Dr. R. V. Tamhane Memorial Lecture is delivered annually by eminent scientists on any topic in Soil Science and Agricultural Chemistry. The 3rd Memorial Lecture was delivered by Dr. J. S. Kanwar at the Andhra Pradesh Agricultural University, Rajendra Nagar, Hyderabad during the 41st Annual Convention of the Indian Society of Soil Science on June 18, 1976.

About the Speaker

Dr. J. S. Kanwar is currently working as Associate Director, International Crops Research Institute for the Semi-Arid Tropics, Hyderabad (A.P.). Prior to this, he had several key assignments, namely, Deputy Director-General (Soils, Agronomy and Engineering) in the Indian Council of Agricultural Research, Professor of Soil Science and Agricultural Chemistry and then Director of Research in the Punjab Agricultural University and as Agricultural Chemist of the Department of Agriculture, Punjab. In his capacity as Duputy Director-General of the ICAR he was mainly instrumental in organising and intensifying research in soils, agronomy and water management in the country and initiated a number of important All India Coodinated Projects involving soil, agronomy and water.

His contributions as the Professor of Soil Science and Agricultural Chemistry and subsequently as the Director of Research of the newly founded Punjab Agricultural University will ever remain a record of the important role played by him in planning and laying a strong foundation of agricultural research and education in Punjab. He, along with his other colleagues had to bear the onerous responsibility of creating facilities for soil research and education in Punjab after the (unfortunate) partition of the country.

He was associated with important symposia, conferences, and committees in various capacities such as Member of the UNESCO Advisory Committee on Natural Resources ; President of the Indian Society of Soil Science ; Vice-President of the International Soil Science Society ; delegate to the UN Conference on Human Environment ; Vice-Chairman of Commonwealth Agricultural Bureau Conference held at London and delegate to the World Food Conference in Iowa. He is also a fellow of Indian National Science Academy and was awarded the Rafi Ahmed Kidwai Memorial prize for his contribution to soil research. A sizable number of his publications bear to the testimony of his interest in the various aspects of soil science and agricultural chemistry particularly in the field of soils, water, fertilizers and crop production.

Born on 10th December, 1922 in the village Khera Kalmot, Anandpur Sahib (Ropar) in Punjab, he graduated from the Punjab Agricultural College, Lyallpur (now in Pakistan) and obtained his Ph.D. degree from Australia and also worked as a postdoctorate fellow in U. S. A.