RELATIVE MERITS OF ORGANIC MANURES AND INORGANIC FERTILIZERS.

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Since the time Liebig had propounded his mineral theory of plant nutrition and demonstrated that plant growth could be augmented by the application of inorganic fertilizers, a controversy had started as regards the relative values of organic manures and inorganic fertilizers in crop production. In spite of the fact that the controversy has raged for such a long time, it is unfortunate that there are not many well planned experiments which could give a definite incontrovertible answer to this question. The late Sir A. Howard, one of the indefatigable upholders of the organic school wrote—'The power to resist disease which organic farming and gardening confirm on the plant and on the animal is duly passed on to the mankind'. (Howard, 1946). Dr. E. J. Salisbury, however, stated that—'The presentation of manurial problems as a controversy concerned with organic manures ***versus*** mineral fertilizers is due to confusion of thought and complete failure to apprehend either the fact or the problem.'

The three important functions, among others, commonly attributed to the soil organic matter are: (1) It acts as a storehouse of plant nutrients, (2) It promotes the activity of soil micro-organisms, and (3) It improves the physico-chemical properties of the soil. It has, however, been suggested (Keen, 1946) that addition of organic matter is of doubtful value in tropical and subtropical regions owing to its rapid decomposition under temperature prevailing there. Addition of organic manures has a fertilizing value only and unlike temperate regions there is no improvement in the soil structure (Bear, 1947).

Carbon and Nitrogen contents of soils:

The amounts of organic matter in mineral soils vary widely from soil to soil and even in the same soil type the variations may be considerable according to conditions. In most soils, especially if under similar climatic conditions, (unless they have recently received a large amount of fresh plant or animal residues), there is found a more or less constant ratio of C/N of the organic matter. This ratio ranges from 8 : 1 to 18 : 1, the average being about 10 : 1. Since a rather definite ratio (1 : 1·724) exists between the organic carbon and the soil organic matter (humus), the amount of organic matter that may be maintained in any soil is contingent upon the amount of nitrogen present (Millar *et al.*, 1936).

Economy in the maintenance of Soil Organic Matter:

Every soil has more or less a definite level of organic matter and nitrogen by virtue of its equilibrium with a number of complex interacting factors including climate, natural vegetation and other environmental conditions. The method of handling of the soil such as cultivation, tillage, manurial and rotational practices may disturb this equilibrium quite considerably and consequently its productivity. Maintenance of humus at a very high level inconsistent with that permitted by the soil type, climatic and other environmental conditions would not only be difficult but also expensive. It would, therefore, be impracticable and unwise to attempt a maintenance of soil organic matter and nitrogen above a certain level consistent with crop yields that pay best (Russel, 1927).

Balanced Manuring:

While the bulky organic manures have been in use in various countries as far back as the agricultural records go, the introduction of inorganic concentrates for augmenting crop production is comparatively recent.

Violent attacks have been made from time to time on the practice of using artificial fertilizers and it has been maintained that fertilizers are harmful to the physical and chemical conditions of the soil. Experimental evidence, however, shows that the use of well-balanced fertilizers has given good results comparable to those obtained by the application of bulky organic manures. Moreover, the ratio of plant nutrients can be correctly regulated by use of artificials, whereas the amounts of such nutrients are fixed in organic manures and cannot be altered and this may result in unbalanced manuring of the crop. Injudicious use of fertilizers may on the other hand lead to the deterioration of the crop producing power of the soil. It is to be noted that organic manures also contain micronutrients needed by plants while fertilizers unless specially prepared will not contain these. On this account organic manures are often considered as 'fool proof' in the sense that one cannot go wrong with them, while with fertilizers the application must be done with certain amount of technical knowledge.

The continued use of a single inorganic plant nutrient will, in the course of time, deplete the soil of other plant nutrients and create soil conditions in which crop production is substantially lower. Where, however, suitable fertilizers have been used in correct proportions high crop yields have been obtained and there is no evidence of any soil deterioration. Continuous application of ammonium sulphate at the Woburn Experimental Station, under 50 years of continuous cropping, has resulted in almost complete failure of crops due to the development of acidity, while application of lime has been successful in making it healthy. Similar results were obtained in long term experiments in Pennsylvania, U.S.A.

Response of Crops to the Organic and Inorganic Fertilizers.

The world literature on the comparative values of organic manures and inorganic fertilizers in the maintenance of soil fertility is controversial. As a source of plant nutrients bulky organic manures (e.g. F.Y.M.) contain depending on the source, varying amounts of N, K_2O, CaO, PO_4 and other compounds including micronutrient elements. Unlike inorganic concentrates bulky organic manures may be multifold in their action and besides supplying plant food materials to the soil may have simultaneous effects on the physical, chemical and biological properties of the soil.

In the absence of proper analytical or other data for the materials used and because of omission of treatments involving the addition of equivalent amounts of nutrients in other forms in most of the experiments with bulky organic manures it is impossible to assess the relative merits of organic manures with those of artificial fertilizers. Moreover, as a source of nitrogen F.Y.M. is slower in action and less effective than equivalent amounts of nitrogen in more concentrated and readily available forms such as ammonium sulphate. This is due to the fact that the plant nutrients locked up in bulky organic manures are slowly liberated by the activity of micro-organisms. On this account it is impossible to assess the value of organic manures in a single year or short term experiments and more detailed observation of a long term nature is required. On the other hand, concentrated inorganic fertilizers may be subjected to heavy loss due to leaching, reversion or other causes whereas in the case of bulky organic manures, the constituents being slowly liberated by microbial activity are comparatively less susceptible to such loss. These facts must be taken into consideration in the interpretation of relative merits of organics and inorganics.

Results of Experiments in Foreign Countries:

Bear (1947) has presented evidence from Rothamsted Experiments started in 1852 to clearly show the value of chemical fertilizers in maintaining soil productivity and crop yields. The plot receiving 1,392 lbs. of fertilizers annually out yielded the plot receiving an annual dose of 15·7 tons of manure. This is true not only for the first 10 years and the next 40 years but for the entire 95 years average. The results are interesting and are presented below:

TABLE I.

Plot No.	3	2B	8	7	13
Annual application/acre.	None.	Manure.	Fertilizer.		
			1,392 lbs.	1,192 lbs.	99 lbs.
Period.	Yield (bu)	Yield (bu)	Yield (bu)	Yield (bu)	Yield (bu)
1852–61	15·9	34·2	36·0	34·6	32·9
1862–71	14·4	37·5	40·5	35·8	34·8
1932–42	12·7	26·1	31·0	26·9	25·7
1942–46	15·7	34·3	38·7	35·3	30·8

Bear (1947) concluded that there is no evidence whatsoever that fertilizers when correctly used, cause any deterioration of the soil or have any injurious effects on plants or earthworms or cause any deterioration in the food value of plant products.

On the other hand, the effect of 50 years of continuous cropping with either wheat or barley at Woburn Experimental Station has shown the deleterious effects of the injudicious use of sulphate of ammonia resulting in the almost total failure of the crop. Application of calcium carbonate, however, resulted in restoring the crop yields to the normal. Successful and normal barley plants could be grown on acid soils if organic manure was added. Similar results were obtained from the long term experiments in Pennsylvania, U.S.A. (quoted by Collins, 1947, p. 64) since 1882. Continued use of sulphate of ammonia brought about deterioration of yield at alarming rate but when this was used in conjunction with lime no deterioration was observed.

The importance of manure as a direct source of organic matter in general farming has been rather exaggerated. Any large and dependable increase in soil organic matter will not come from the manure itself but from the greater amounts of roots and crop residues associated with good crop growth. That this can be achieved by the judicious use of fertilizers also is shown by the results obtained at the West Virginia Experimental Station (Table II).

The content of organic matter to plough depth was increased by the use of purely mineral fertilizers from 42,800 lbs. to 60,800 lbs. This was obviously due to greater amounts of roots and other residues that were left behind on and in the soil by the nearly triple crop yields resulting from the use of fertilizers. Somewhat higher yields were obtained by the use of organic manures but it must be observed that the doses of manure applied were heavier than fertilizers.

Keen (1946) holds the view that because of the rapid decomposition of organic matter under tropical conditions, the beneficial effects of bulky organic manures lie not so much in securing a physical improvement of the soil as in supplying plant

TABLE II.

(All figures for 15 years duration calculated on acre basis).

Material applied.	Quantities applied (tons)	Amounts of			Total crop produced (lb.)	Organic matter in plough depth (lb.)
		N (lb.)	P_2O_5 (lb.)	K_2O (lb.)		
None	Nil	Nil	Nil	Nil	40,960	42,800
(*) Fertilizers ..	5	627	627	812	117,910	60,800
Manure	190	1,900	950	1,900	139,670	73,600

nutrients that are contained in the manure. A number of experiments showed that large increases in yield were obtained by applying their ashes rather than by digging in green manure crop (Faulkner, 1934; Lewin, 1931). Doyne (1937) found that a marked increase in the carbon and nitrogen content of the soil was brought about by green manuring but the effects were transitory and within less than a year of being ploughed in, the plant residues had decomposed so effectively that there was hardly any trace left of them.

One of the important functions of organic matter in the soils is to build up a structure resistant to erosion. Organic manures do not appear to be so efficient in this respect in tropical as in temperate regions. Experiments in Uganda showed that soil structure can best be protected against erosion by growing a grass crop in the rotation (Uganda Department of Agriculture Report for 1942). Crowther (1943) has pointed out that the beneficial effects of rotation of cereal crops with roots and leys in the improvement of the soil fertility are brought about '*in ways which cannot be imitated by added organic manures*'.

Results of Experiments conducted in India:

Although a fairly large number of trials have been conducted in the past with different types of organic manures in India and in major cases their values appreciated, yet in judging their relative merits with those of artificial fertilizers one would be left with confusion. In most of the experimental works attention has been concentrated mainly on F.Y.M. and the various oil cakes commonly produced in India, and on ammonium sulphate. Experiments with other soluble forms of nitrogenous fertilizers like sodium nitrate, calcium cyanamide, ammonium nitrate and urea are fewer in number. The majority of the experiments have centred around only one point, viz., the relative values of nitrogen in the manures and fertilizers without any consideration whatsoever, for the probable effects due to other food elements contained in the bulky organic manures in addition to those added in the form of inorganic fertilizers used for comparison. Moreover, proper analytical data for the soils, manures and crop are lacking. In view of these only reasonable generalizations, though not strictly accurate can be made regarding the relative merits of organic manures and inorganic fertilizers.

(a) Experiments of less than 5 years duration.

In short term experiments of less than 5 years duration the artificial fertilizers have given the highest yields and maximum response per unit of nitrogen in the majority of cases in Madras, Bombay, Bihar and Orissa, Madhya Pradesh and

* Fertilizers contain a mixture of sodium nitrate, superphosphate and sulphate of potash.

Assam. In Aduthurai and Nanjanad in Madras, in Waraseoni and Powerkhera in Madhya Pradesh and in Karimganj in Assam, mixtures of artificials and organics have proved better than either of them alone both as regards total yields as well as response per unit of nitrogen. In Koilpatti (Madras) groundnut cake plus super and sulphate of ammonia plus super were alike and were significantly better than no manure in the case of cotton, cambu and cholam.

In Berar Farm (Madhya Pradesh) groundnut cake at 20 lbs. N/acre on cotton gave 30% increased yield over no manure, whereas with sulphate of ammonia alone (20 lbs. N per acre) the yield was only 2% over no manure.

(*b*) *Experiments of 5–10 years duration.*

The general trend of these experiments is that as a source of nitrogen artificial fertilizers prove better than organics (F.Y.M. cattle manure), in earlier years, whereas the effects of the latter gradually show up only in the later periods. In Aduthurai (Madras) with nitrate and mixture of green leaf and nitrate in different proportions (to supply 20 lbs. N/acre) it has been observed that in the first two years nitrate alone gave the maximum yield of paddy per acre; in the third and fourth years nitrate and a mixture of nitrate plus green leaf were equally good, whereas in the fifth year nitrate plus green leaf proved superior to nitrate alone. Similar results were obtained in Coimbatore (Madras). In Nanjanad (Madras)—sodium nitrate gave highest yield of potato in the early years but by its constant use the yields were deteriorated due to its harmful effects. In Mangalore, Dharwar, Surat and Manjri in Madras—the inorganic forms of nitrogen (ammonium nitrate, ammonium sulphate) proved better than organic forms in the case of paddy, jowar, cotton and sugarcane respectively. In Lyallpur (Punjab)—both sulphate of ammonia and F.Y.M. were alike as sources of nitrogen on sugarcane and wheat.

In Akola (Madhya Pradesh) 9 years of experiments on cotton showed that poudrette and saltpetre were alike and gave better response (7·6 lbs. and 7·5 lbs. cotton/lb. N) per unit of nitrogen than cattle dung (3·6 lbs./lb. N). In another experiment in heavy black cotton soil, the highest response over no manure was given by F.Y.M. (10·8 lbs./lb. N) followed by saltpetre plus bone dust (9·5 lbs./lb. N) and poudrette (8·1 lbs./lb. N). In Tharsa experiments for 6 years, the responses from oil cake and ammonium sulphate were respectively 10·3 lbs. and 7·5 lbs./lb. N over no manure. Cattle dung gave a response of only 3·5 lbs. of wheat/lb. N. With sugarcane, however, for a period of 5 years til cake plus ammonium sulphate gave the highest yield followed by til cake alone. Cattle dung was least effective when applied on equal nitrogen basis. Experiments in Labhandi (Madhya Pradesh) for 7 years on irrigated wheat showed highest response in favour of poudrette (16 lbs./lb. N) followed by bone dust plus nitrate (13·7 lbs./lb. N). In Adhartal (Madhya Pradesh) different manures and fertilizers have been tried on paddy on equal nitrogen basis (20 lbs. N) on a Sehra soil (light-sandy loam) for a period of 6 years. Poudrette, cattle dung and bone dust gave significant response over no manure, the responses being respectively 30·5 lbs., 21·0 lbs. and 21·0 lbs. of paddy/lb. over no manure. Effects of fertilizers like ammonium sulphate and calcium cyanamide were non-significant (4·5 and 2·0 lbs./lb. N respectively). Experiments on irrigated wheat showed that a mixture of cattle dung, ammonium sulphate and super gave higher response per unit of nitrogen than cow dung alone.

(*c*) *Long Term Experiments (above 10 years).*

In Pratapgarh (U.P.) 16 years of experiment with paddy showed that a mixture of ammonium sulphate and bonemeal (16 lbs. N/acre) gives the highest response (26·9 lbs./lb. N) followed by cattle dung (6·8 lbs./lb. N) and neem cake (5·4 lbs./lb. N) over no manure.

In the black cotton soil Nagpur (Madhya Pradesh) 15 years of study on wheat with different fertilizers and manures has been recorded. In the first 11 years the amounts of nitrogen varied widely among different treatments. A mixture of saltpetre (240 lbs.) and bone meal (360 lbs.) gave the highest yield (117% over control) followed by saltpetre (240 lbs.) and cattle dung (160 mds.). The differences between these treatments were not significant. Manuring was, however, changed on an equal nitrogen basis (40 lbs. N/acre) during the last 4 years. Cattle dung showed the highest increase (122% over control) in yield followed by saltpetre (98% over control) and saltpetre plus bonemeal (86% over control). In Labhandi (Madhya Pradesh) experiments on irrigated paddy, poudrette showed the highest response (39·5 lbs./lb. N) followed by castor cake (36 lbs./lb. N) and bone dust plus ammonium sulphate (35·0 lbs./lb. N). In the case of unirrigated paddy poudrette was most effective and cyanamide the least.

(*d*) *Permanent Manurial Experiments.*

In the Permanent Manurial experiments at Pusa (Bihar) during the period 1908–30, it was found that complete fertilizer treatment gave yields which were equal and in some cases more than those obtained by applying F.Y.M. or green manure. The New Manurial series at Pusa laid out in 1932 confirm the above observation. Combination of N and P fertilizers have proved superior to N alone.

In the Permanent Manurial experiments at Coimbatore (started in 1908) it was observed that except in the case of sorghum, complete fertilizer treatment gave better results than cattle manure. In the case of sorghum, effects due to these treatments are about the same.

Carpenter (1938) observed that with tea in Assam, sulphate of ammonia is at least as efficient as, if not more than, an equivalent of organic manure in maintaining both the quality and quantity of the yields.

In the Permanent Manurial experiments at Kanpur considerable deterioration in soil has been observed in plots treated with sodium nitrate and sodium nitrate plus super. Cow dung and sheep penning treatments have preserved the soil from deterioration. At Mysore a mixture of groundnut cake and ammonium sulphate was found to be better than ammonium sulphate. Deterioration of soil has been found to occur in the long run by continued use of inorganic fertilizers unless supplemented by organic manure (Kalamkar and Sripal Singh quoted by Burns, p. 59).

Other Effects of Organic Manures.

Effect on Soil Structure:

Organic manures have been credited with the property of improving the soil structure. No critical experiments of a long standing nature to test this are available at present. Aldrich *et al.* (1945) have shown by laboratory methods that soil treated with different nitrogenous manures and fertilizers have their percolation rates in the following decreasing order:

Calcium Nitrate—Urea—Ammonium Sulphate+lime—Sodium Nitrate+ Gypsum—Manure—Ammonium Sulphate—Sodium Nitrate.

Klintworth (1945) was unable to find any permanent improvement in the structure due to incorporation of organic matter, though he found that there was temporary effect. Keen (*loc. cit.*) however, does not believe that organic matter is responsible for any improvement in structure in tropical areas. He attributed any such effect more to the action of leys and root effects. It appears that bulky organic manures and inclusion of grasses and legumes in the rotation help the formation of structure in soils.

Effect on Nutritive Quality of Crops:

There is a belief that organic manures possess fertilizing properties in addition to those due to various plant nutrients that they contain. Convincing scientific evidence in support of the above is, however, lacking. The alleged value of auximones, vitamins and such compounds in composts, which are said to improve the quality of the crops and confer immunity from disease to plants, is by no means scientifically established. Direct tests for vitamin B_1 content in wheat with continuous manuring for over 90 years gave a 20% higher value for wheat fertilized with inorganics than with F.Y.M.

The studies of Bottomly, Mockridge and others showed that organic manures contained auxins and other plant hormones. Later vitamin B_1 as also other B group vitamins have been shown to be present in organic manures like farm-yard manure and compost. These studies probably formed the nucleus on which the organic school built one of its most imposing edifices. McCarrison and Viswanathan (1926) have claimed an increase of 15% in 'B' vitamins of crops by application of cattle-dung to the soil. These claims have been contradicted by later workers (Harrison, 1934; Leong, 1939; Tanner *et al.*, 1947). Burkholder and Gorfinkel (1948) conclude that though soils under certain conditions provide these vitamins it is not known whether plants utilize them and profit by their use.

Crowther (1949) in summarizing the present position says, 'Although interaction between plants and micro-organisms may depend in part on vitamins, hormones, and antibiotics, there is as yet no clear evidence that the traces of these substances present in animal manures and composts have any practical significance in soil fertility and crop production.'

Another contention of the organic school is that communities of people living on crops produced with organic manures are healthier than others living on crops produced on fertilizers. Critical experiments are lacking in this field. Two experiments, one in Germany and the other in America, have shown no such effect. In the Munich experiment boys 14–17 years were fed on vegetables from organic manured plots while a parallel set of boys were fed on vegetables fertilized with inorganic fertilizers. No difference was observed in a period of 4 years (Wendt, 1944). In the American Experiment quoted by Ogg (1947) a comparison was made of grass from organic manured plots with grass from water culture which was free from organics. No evidence was found to show that the inorganic fertilized grass was inferior to the other set in nutritive quality. The fact that countries using fertilizers in large quantities have a general standard of health much superior to others which depend on organic sources as plant foods, is a strong argument against any prejudice for fertilizers.

General.

The common trend of the cultivators is usually to go towards the use of organics partly due to their low cost and availability and partly due to their age old familiarity for generations connected with the belief that artificials would bring down soil fertility. In view of the present agricultural development facing the country it would not be wise to condemn the use of artificials, as it will be seen that mixture of inorganic fertilizers used in correct proportions can increase crop yields to a very high extent.

In Japan yields of rice per acre have increased by 70% during the 65 years period (1879–1942). Two factors appear to have been primarily responsible—use of commercial fertilizers and better varieties. It seems to be the general belief in Japan that the better varieties produced in recent years are better only when heavily fertilized and also that the better varieties must be grown if the full benefit of the fertilizers is to be expected. In the case of wheat also the interrelation between variety and fertilizer have been emphasized by Japanese Investigators.

This relates not only to the quantity of fertilizers used but also to the particular kind.

The bulk of the evidence on this important aspect of the problem indicates that under Indian conditions the use of a combination of organic manures and fertilizers would give the optimum results both in long and short term planning for improving soil productivity and maintaining soil fertility. Every attempt should therefore be made to conserve and utilize indigenous resources of organic manures to the fullest extent but it must not be forgotten that organic manures themselves will not be able to furnish the needs of Indian soils in entirety. The fertilizer ingredients of organic manures are not only slowly available but also not properly balanced, lacking specially in phosphate.

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