https://doi.org/10.29321/MAJ.10.A04337

On Planning Manurial Experiments in Sugarcane in Madras State

By

S. V. PARTHASARATHY, M.Sc.,
Sugarcane Research Station, Anakapalle

Introduction: In increasing yield per acre, varieties and manures constitute the two major factors. The problem is a complex one and as such there is still some gap in our knowledge and also between the experimental results and ryots' field practice.

From 1914 to 1950, there have been 38 experiments in representative sugarcane tracts of this State on manuring sugarcane. Of these, 16 were at Anakapalle, 8 at Samalkot, 8 at Palur and 6 at Gudiyattam. In spite of the large number of experiments laid out, the quantitative knowledge in respect of manuring the crop is not advanced very much. The results of experiments recorded year after year are so varying that conclusions based on three-year data have been of only qualitative value. Further, the results of these experiments were not tested in ryots' fields and therefore are not very helpful in extension service. It is therefore desirable to critically review the manurial experiments, to detect the causes for the fluctuating results recorded and to explore the possibilities of better technique for future experiments.

Review: A complete list of experiments so far conducted in this State is shown in appendix 1. A scrutiny of the treatments in the various experiments as shown in column 3 indicates that prior to 1930, the manurial doses were determined on the bulk of manure and not based on chemical analysis of the manurial constituents. The experiments were also not laid out on the modern techniques which lend themselves to statistical analysis. This period is also characterised by the exotic types: J. 247, Purple Mauritius and Fiji B being the main varieties under test. Nitrogenous and bulky organic manures were chiefly tested during this period.

Farmyard manure, green manure, cakes and fish-guano were the manures under test till 1925, after which ammonium sulphate also entered the field. The average yield recorded in most of these experiments was low as compared to the yields recorded in later years. This low yield was due to varieties, which were later ousted from cultivation by the Coimbatore canes and also due to the form of manures in use then. Farmyard manure recorded better results than no manure, but fish guano proved better than farmyard manure. Even the application of 30 tons of farmyard manure did not equal 10 bags of castor cake. These experiments therefore established the superiority of cakes over green manure or farmyard manure. Dr. Rege (1941) also pointed out that the value of cattle manure as a nitrogen supplier was not much.

From about 1925, ammonium sulphate came into use as a fertiliser for sugar cane. Experiments comparing this with cakes and cattle manure, revealed the superiority of the fertiliser in increasing

yields. Even when it was applied on Nitrogen basis, this fertiliser recorded greater increases in yield than cakes. But, beyond certain levels it depressed juice quality, whereas this depression was not so marked, when cakes were applied. It was therefore brought out that if high yields and good quality jaggery are to be aimed at, there is need to mix the cakes and fertilisers in proper proportions.

The experiments that were laid out after 1930, are therefore on considerations of (i) form of nitrogen and optimum proportion between different forms (ii) Manures being applied based on chemical analysis of ingredients involved (iii) statistical analysis of yield data (iv) Co. canes being the main varieties under test (v) the value of other nutrients such as P and K being evaluated. It may therefore be considered that the manurial experiments in the last two decades were on sound lines.

These experiments indicated that the optimum doses of nitrogen for the different tracts were as follow :

Anakapalle	...	100 lb. N per acre.
Samalkot	...	150 lb. N per acre.
Gudiyattam	...	200 lb. N per acre.
Palur	...	250 lb. N per acre.

In regard to the form of nitrogen, a proportion ranging from 1 : 1 to 3 : 2 between cake and ammonium sulphate was considered good. The experiments now in progress at five centres, have indicated no difference in yield or quality due to form of manure. But this should be tested by permanent manurial experiments to bring out the cumulative effect of each form of manure. The experiments on time of application indicated that application of the entire dose at planting time was not good ; application in 2 to 3 doses was more efficient. Late application of the manure, i. e. beyond the fourth month of the crop, depressed juice quality. Basal dressing with farmyard manure did not influence yield or juice quality, though small beneficial effects were discernible during periods of drought.

Potassium did not influence either yield or quality ; in certain cases it even depressed yields.

Phosphates did not influence yield or quality. It did not improve setting of jaggery nor the keeping quality. However, there is still an impression in certain quarters that phosphates improve setting of jaggery.

The experiments so far conducted have clearly indicated that nitrogen in organic and inorganic forms mixed in certain proportions, is the only ingredient that records increase in yield, while potassium and phosphates have little effect on yield or quality.

III. **Fluctuations in recorded data** : The chief mode of interpreting the results was by averaging the recorded yield data. Results recorded in column 10 of the appendix 2 show that the actual responses to manuring from year to year had been very widely varying.

The variations are far beyond what may be attributed to experimental error. In the past, these wide variations have been ignored in interpreting the data, though this does not seem to be justifiable. It is necessary to analyse the basic causes for such fluctuations in the recorded yield-responses to manures.

(a) *Soil fertility:* The basic fertility of the plot in which the manurial experiments have been laid down was not considered in arriving at the quantum of added nitrogen or in interpreting the data. That such basic fertility of soil have a large influence on yield fluctuations is brought out at Palur in a series of manurial experiments, which alternated in two sets of fields from year to year.

TABLE I.

Variations of yields in Manurial Experiments at Palur.
(Weight of canes in tons per acre.)

Dose of N lb./acre	Field Nos. 31 to 34			Average for 3 years	% over 50 N	Fds. No. 24—27		Average for 2 years	% increase over 50 N
	1928–'29	1930–'31	1932–'33			1929–'39	1931'–32		
50 N	21·8	17·9	20·5	20·1	100·0	13·3	9·9	11·6	100·0
100 N	24·5	21·5	25·00	23·6	117·4	21·6	17·6	19·6	168·6
150 N	32·3	26·7	33·4	31·0	154·2	32·3	28·7	30·5	263·0

If the manurial experiments are to give precise indications on the quantities of nitrogen to be added, three important factors should be considered viz., variety, soil and water. For such a step, a workable method of estimating the nitrogen available from soil must be determined. If chemical analysis of soil does not directly indicate the quantum of nitrogen to be added—and generally it may not—other methods of determining this must be evolved. In all the agro-biological experiments (Willcox, 1930) the N present in the soil must be taken into account, if the quantum of nitrogen to be added is to be predetermined. If not, the plant itself is to be used as an index during its growth to determine whether the growth is taking place under sufficiency or deficiency levels of nitrogen in plant tissues (Craig 1939). Addition of a fixed quantity of nitrogen by time schedule irrespective of the initial quantities present in the soil and the rate of its utilisation by the crop cannot offer precise data on the quantitative relationship between nitrogen and yield. The large fluctuations in experimental results from year to year in manuial experiments is due to such defects in the experiments.

(b) *Water:* That water is an important factor in the proper utilisation of the added manure needs no emphasis. In none of the manurial experiments, was this factor strictly controlled or evaluated. The quantity of water to be added by irrigation cannot be determined by mere acre-inches or by frequency of irrigation. Similarly the value of rainfall cannot be evaluated by total fall or by rainy days. The relationship of water to growth should be considered in terms of soil moisture and availability of water to the plant from the soil. Water in

the soil has three important roles in relation to manuring viz., (i) it determines soil aeration, biological and chemical activities in the soil (ii) as a solvent for plant nutrients, it determines uptake of nutrients by the plant, (iii) under excess-conditions, it leaches out the nitrogen beyond the reach of roots of the plant. In other words it determines the release of nitrogen by the soil or added manure, the loss due to leaching and the uptake by the plant. In all these three ways, water is an important factor to be taken into consideration in evaluating nitrogen of the manures or soil. At Gudiyattam, which receives insufficient rainfall in South-West Monsoon, the relationship between water and nitrogen-utilisation was brought out in an experiment. When the plots receiving 200 lb. Nitrogen per acre were irrigated frequently, the crop arrowed profusely and ceased growth earlier than in the plots receiving irrigation at longer intervals. The crop growth in plots with frequent irrigation was similar to the plot receiving low Nitrogen dose.

A review of the yield data in the manurial experiments of different Research Stations as related to rainfall, shows some interesting indications.

In the manurial experiments at Anakapalle between 1933—'36 to 1935—'36, response to Nitrogen was nil in two years, and good in one year. The yields of jaggery at 25 N were 828 lb., 10,449 lb. and 9,025 lb., while those for 100 N were 9,444 lb., 13,555 lb. and 7,175 lb., respectively. In the second year, there had been some depression in yield. The years 1934—'26 recorded very hot weather. But the two monsoons were favourable in 1934—'35 while drought continued in 1935—'36. The response to manure was good in 1934—'35 while there was no response but only a depression in 1935—'36.

In the series of experiments from 1944—'45 to 1946—'47, canes were damaged in the first year due to lodging and in the second year by cyclone. In the third year yield differences between Zero N and 250 lb. Nitrogen were not significant.

In the graded dose N experiments laid out at Palur, there was good response to manuring in 1943—'44 and 1946—'47 but very little in 1944—'45, and 1945—'46. In the year of good response, the South-West Monsoon was well distributed. When there was drought, the manure was not utilised.

In the experiments at Gudiyatham, the response was graded for increasing doses in 1946—'47 while in 1945—'46, the dose 100 N came under one bar. In 1945—'46, there was 14·73 inches of rain in 19 rainy days in July–August, while in 1946—'47 there was only 6·55 inches in 16 rainy days. Receipt of good showers pulled up the crop and the manure was efficiently utilised. There was drought in November–December. Late receipt of showers in 1946—'47 may be responsible for graded response to manure in this year.

The yield data from manurial experiments are variable from year to year due to variable soil moisture, depending upon rainfall and its distribution.

What are considered as optimum doses for the different tracts is already mentioned. A scrutiny of this variable optimum indicates the possibility that the increasing dose of Nitrogen from northern to southern regions is closely linked with the soil - moisture - plant relationship in these tracts. The northern districts which receive good showers in South - West Monsoon recorded high - yields with 100–150 N, while the southern districts which receive poor showers in South - West Monsoon required higher doses of Nitrogen. In areas subject to limited supply of water, larger doses of Nitrogen are needed. Studies at Anakapalle revealed that when water supply is copious throughout the life - cycle of the crop, loamy and clayey soils show equal crop - producing potentialities, while when the water supply is at deficiency levels the lighter soil withstands drought better and utilises manure better than the clayey soil. At about 10% soil moisture, the crop in loamy soil grows up well, while it exhibits deficiency of moisture in clayey soils. The type of soil in relation to soil moisture and crop growth is important in studying manurial needs of the crop.

From the above it is clear that the recorded data are variable and due to lack of information on soil moisture status, the response to nitrogen in the different Agricultural Research Stations cannot be expressed in quantitative terms.

IV. **Some practical aspects:** Some broad indications from the different manurial experiments have been stated above. It is necessary to examine the practical bearing of the above experiments in field practice.

A thirty - ton crop of sugarcane removes the following ingredients from an acre of land.

TABLE II.

Plant nutritional elements removed from soil.

Elements	30 ton crop of Co. 419. lb./acre.	3 tons jaggery lb./acre.
Nitrogen.	69·7	1·9
Phosphoric acid.	132·8	7·8
Potash.	261·3	16 0
Lime.	265·6	12·0

Only a small fraction enters in the final product, while the rest are left in the crop residues as waste products. In the case of sugar, none of the manurial ingredients are found in it and as such it should be theoretically possible to return to the soil all that is removed by the crop. In the case of jaggery some proportion of the manurial ingredient are found in jaggery and a 30 - ton crop will remove nutritional elements as shown in table above.

Cane tops are used for feeding cattle and begasse for feeding the furnace. Therefore, in factory or jaggery areas some amount of trash is available as a waste organic material. When the trash is composted and returned to soil it is possible to return 50 lb. Nitrogen through waste products.

In many tracts, it is possible to raise a crop of sunnhemp or other green manure crops either preceding the crop or as an intercrop. By this system, about 40 lb. Nitrogen may be added to the soil per acre. The review by Dr. Rege indicates that there is greater availability of nitrogen by green manuring. Thus, it is possible to add not less than 50—60 lb. Nitrogen to the soil if one of the methods mentioned above is adopted.

Oil-cakes are nowadays rather costly and ammonium sulphate was difficult to secure until recently. The Venkataraman Committee (1950) reported that the manurial bill constitutes upto 30% of the total cost of cultivation. Therefore, the best way to manure sugarcane is to apply as much Nitrogen possible by utilising the waste products and supplementing the same with green manures, and ammonium sulphate. This method is the cheapest for the cane grower and also the best in respect of national economy in which soil fertility is maintained and cakes may be spared as cattle feed. Such agricultural practices will encourage automatic recuperation of soil without importing costly materials from outside the field for the purpose.

In recent years, due to high cost of oil-cakes and ammonium sulphate and also due to non-availability of these in the open market, cane growers have been purchasing manure mixtures from different firms. A list of firms which prepare and sell special mixtures for sugarcane and the chemical analysis of these are furnished in table III.

TABLE III.

Name of the firm	Name of mixture	Guaranteed analysis Nitrogen Organic	Nitrogen Inorganic	P_2O_5	K_2O
1. The Scientific Fertiliser Co., Ltd., Coimbatore	Sugarcane fertiliser	1·5	15·5	1·5	...
2. Mysore Fertiliser Co., Madras	Sugarcane Special	1·7	13·3	4·5	...
3. Nilgiri Fertiliser Ltd., Coonoor	Sugarcane fertiliser	1·5	11·07	3·5	2·0
4. Premier Fertiliser, Ltd., Tanjore	Sugarcane fertiliser No. 1	4·0	3·0	5·6	...
	No. 2	4·0	5·5	6·5	...
5. T. Stancs Co., Ltd., Coimbatore	Sugarcane manure	2·8	10·2	4·4	...
6. The Cochin Fertiliser, Ltd., Trichur..	Special Sugarcane manure mixture	2·4	11·6	4·2	...
	Sugarcane fertiliser	4·8	5·5	4·5	...
7. Jupiter Manure and Bone Mills, Ltd., Kakinada	Delta Sugarcane fertiliser	3·55	8.16	5·0	0·5

Name of the firm	Name of mixture	Guaranteed analysis Nitrogen Organic	Nitrogen Inorganic	P_2O_5	K_2O
	Sugarcane Special	3·55	9·60	7·0	0·4
	Tapeswaram sugarcane fertiliser	1·30	10·30	4·2	0·5
	Polnadu Sugarcane fertiliser	2·00	12·00	6·0	...
8. A. S. T. F. Rodrigues & Co., Katpadi	Sugarcane mixture	1·65	8·82	5·50	...
	Sugarcane special	3·31	12·32	5·50	...
9. Parry Co., Ltd.,	Karur Sugarcane fertiliser	0·8	13·2	6·0	...
	Samalkot Sugarcane fertiliser	0·8	13·2	6·0	...
	Sugarcane special mixture	2·5	12·4	1·8	...
	Cuddalore sugarcane A.	4·1	4·9	5·6	...
	Cuddalore sugarcane B.	5·4	4·9	2·2	...
	Cuddalore sugarcane No. 1	3·8	6·6	1·0	...
	No. 2	4·9	6·4	3·8	...
	Samalkot sugarcane A	1·3	6·4	1·0	...
10. Coimbatore Chemicals & Fertilisers, Ltd., Pottanur	Sugarcane mixture	1·4	8·2	8·0	...
11. Deccan Fertiliser, Co., Coimbatore	Sugarcane fertiliser	2·6	8·4	9·0	...
12. C. Raju, Kakinada	Sugarcane mixture special	3·4	9·1	5·0	...

Even though experiments at various Research Stations in this State have shown that phosphates do not increase either yield or quality, all the firms adopt a formula in which some quantity of phosphates are included. Phosphates are useful to grain crops in increasing yields, particularly to paddy. Therefore, application of phosphates to sugarcane crop, when there is no immediate use for this ingredient is to be considered a waste. If there are phosphate-deficient soils or pockets in the sugarcane tracts of this State, they still remain to be detected. If the popular impression that phosphates improve setting of jaggery, not confirmed by experiments of this Department, is true, even then phosphate need not be directly applied to sugarcane. A better way should be its application to the preceding crop of paddy and and leaving the residual effect to sugarcane, or better still, will be its application to the preceding green manure leguminous crop, as is being recommended by the Government Agricultural Chemist on the T. V. A. system.

Thus, apart from other aspects to be detailed hereafter, the practice by ryots is neither aimed at cheapening the manure bill nor at natural

improvement in soil condition that will increase efficiency in utilisation of the available soil nutrients. The experiments on Research Stations have been mostly confined to import of outside materials, ignoring the natural recuperating power of soil. Such aspects of manuring have not been taken up in any of the manurial experiments as the latter have always been planned on a short-range policy.

V. **Suggestions:** In the design of manurial treatments in the past, cakes and ammonium sulphate played important roles. In supplying bulky organic manure, farmyard manure was the main source. Under ryots' conditions, farmyard manure is not available in sufficient quantities for application to crops. Cakes are valuable as cattle feed and can be used for better purposes than being buried in the soil. In recent times, it has become a scarce and also costly commodity. The best agricultural system is one which uses farm wastes and also which permits raising legumes to recuperate the soil. In the case of sugarcane, a great deal of organic wastes is available at harvest time and these must be utilised properly to increase the organic matter of soil. Secondly, in most places sunnhemp or daincha can be raised preceding cane; where it is not possible to do so, the green manure crop can be raised intersown in cane in early stages. These two possibilities for increasing the humus of soil must be tested on a long-range basis.

The experimants so far conducted reveal that ammonium sulphate is superior to cake in increasing yield of cane, but cake is superior in respect of quality. The possibility of increasing yield and quality by increasing humus of soil as described before and using ammonium sulphate only as fertiliser, leaving cake for other better uses, needs to be investigated.

Phosphates have not increased yield or quality. So also other elements. But such experiments were conducted for short periods only. Under ryots' conditions, there is a fall in yields in the course of a decade or so and change of variety is considered necessary. Recent experience in Bombay indicates that even change of seed by importing from a distant place increases yield. In all these cases, soil deterioration is suspected to be the cause. There is need to investigate this aspect also. Complete analysis of soil and plant, including the minor elements in plots laid down on a permanent basis to test efficacy of the different organic and inorganic forms, also seems necessary.

In recent times, manurial requirements of crops are sought to be studied by (1) agro-biology (2) foliar diagnosis (3) initial fertility tests on soil by chemical analysis or by using indicator plants (4) by studying intensity of nutrition by the plant. In the experiments so far conducted no such criteria were adopted. After the manure was applied, only the yield was considered, ignoring the physico-chemical-biological changes in the soil during crop growth and the reactions of the plant to the existing growth factors. The law of diminishing returns was the only consideration, while the law of growth factors and the law of limiting factors were ignored.

Certain precautions seem to be necessary in order to ensure uniformity in yield data from year to year and to assess the value of

added Nitrogen in quantitative terms instead of arriving at empirical conclusions by averaging the results, a process which ignores variations and their causes.

In the recent experiments at Anakapalle both the soil and the plant were analysed periodically and this gaves more precise information than similar experiments laid out previously on the station. An attempt is being made to see if foliar diagnosis could be taken as a reliable index for the application of Nitrogen to the soil. Similarly studies on water requirement revealed that irrigation based on soil moisture can give definite data while irrigations based on intervals alone do not yield quantitative information. Another important factor for variation in yield from year to year is the variation in population.

VI. **Conclusion:** Certain modifications in the present technique of conducting manurial experiments are necessary. The modifications suggested are (1) periodical soil and plant analysis (2) studies in soil moisture (3) ensuring uniformity in stand and working up to minimum population. For the adoption of the first two, the Research Stations, are to be equipped with staff and other facilities; but it is worthwhile doing it even at some cost. If not, the data collected even during the course of long periods, do not furnish definite knowledge on the scientific application of manures. Under the present conditions, there are losses due to wastages in applied manure, or insufficiency in applied manure. When the experimental results are analysed, the scientific criteria should be immediately tested in ryots' plots to assess the fertility variations in the tract and the application of farm data to field conditions.

LITERATURE CITED:

Annual Report of Sugarcane Research Scheme, Anakapalle and Gudiyattam (1947—48—50—51.)

Craig (1939) Tenth Annual Report of the Sugarcane Research Station, Mauritius.

Lakshmikantham M. (1949): Optimum Nitrogen requirements of Sugarcane in Anakapalle. Madras Agricultural Journal. XXXVI. p. 12.

Madras Agricultural Station Reports (1912—'13 to 1947—'48.)

Noel Deer (1921) Cane sugar. Norman Rodger, London.

Paddy Specialist and Government Agricultural Chemist (1944): A Review of manurial experiments on the Agricultural crops of the Madras Presidency for the decennial period (1930—'40.) Madras Agricultural Journal XXXII. p. 3.

Rege R. D. (1941): Fertiliser experiments on sugarcane in India (1932—'39) Indian Council of Agricultural Research Publication.

Stewart A. B. (1947): Soil fertility investigations in India with special reference to manuring: Indian Council of Agricultural Research Publication.

Vaidyanathan M. (1934): Analysis of manurial experiments in India. Indian Council of Agricultural Research Publication

Venkataraman Committee (1950): Report.

Willcox O. W. (1930): Principles of Agrobiology. Premier Publishing Corporation, New York.

APPENDIX I.

Summary of Manurial Experiments in Madras State

Station	Year	Manurial Treatments	Results.	Remarks
Anakapalle	1916—17 to 1918—19	Variety J. 247 : Cattle manure 30 cartloads – wild indigo 2000 lb., cattle manure 30 cartloads – castor cake 820 lb, green manure–castor cake 1640 lb. compound.	No definite conclusions were drawn.	Red rot and high variations in plot yields vitiated results.
	1919—20 to 1922—23	Variety J. 247 : Fish guano ½ ton – 4,000 lb, wild indigo, Fish guano 1 ton compared.	Fish guano at 1 ton per acre recorded higher yields.	
	1923—24 to 1931—32	Variety J. 247 : 15 cwt. groundnut cake, 10 cwt. groundnut cake – 2000 lb. vempali, 8 cwt. groundnut cake – 4000 lb. vempali, 1 ton groundnut cake.	No significant differences were evident between treatments.	The treatment 1 ton groundnut cake was included in 1925-26.
	1929—30 to 1932—33	Variety J. 247 : (10,000 lb. cattle manure–2000 lb. wild indigo–640 lb. groundnut cake), (10,000 lb. cattle manure–2000 lb. wild 260 lb. ammonium sulphate), (27,665 lb. cattle manure–2000 lbs. wild indigo) compared.	Substituting cattle manure by ammonium sulphate to give 54 lb. Nitrogen, increased yield. 260 lb. ammonium sulphate can replace 7½ tons cattle manure.	

APPENDIX I—*(Continued).*

Station	Year	Manurial Treatment	Results	Remarks.
	1933—34 to 1935—36	Variety Co. 213: *Inorganic Series:* (i) No manure, (ii) 100 N as ammonium sulphate, (iii) N-K (100 lb. N as ammonium sulphate–100 lb. K_2SO_4,) (iv) N-P (100 lb. N as ammonium sulphate–300 lb. superphosphate) (v) N–K–P (100 lb. N as ammonium sulphate–9300 lb. super–100 lb. K_2SO_4) (vi) K–P (100 lb. K_2SO_4 – 300 lb. super), (vii) to (xii) same as (i) to (vi) with basal dressing of farm yard manure at 5000 lb/acre.	KNP is not better in yield over N alone; organic series better in juice quality than inorganic series. No difference between farmyard manure and no farmyard manure plots in inorganic series. K and P did not recard any difference in quality over N alone plots.	Due to heavy rains and cyclone in October of 1933 the crop was lodged and damaged. 1935–36 season was abnormal with inadequate rainfall. No differences were evident between treatments.
	1934—35 to 1935—36	*Organic Series.* (xiii). No manure, (xiv) 100 N as groundnut cake–50 lb. K_2O as ashes, (xv). 100 lb. N as groundnut cake, (xvi). N–P (100 lb. as groundnut cake–300 lb. P_2O_5 as bonemeal 750 lb. K_2O as ashes), XVIII K–P (50 lb. K_2O as ashes–300 lb. P_2O_5 as bonemeal).		
	1934—35 to 1935—36	Variety Co. 213: Variety x spacing: 25,50,75 and100 lb. Nitrogen x (3-5), (4–4), (5–5–), (6-4) links spacing.	Yields greater in medium spacing (3–5) and 4–4) than in wider spacing; yields under lower dose of manure as good as higher dose of manure. Quality of juice better under lower doses of manure.	

	1943—44 to 1946—47	Variety J. 247 : Intensively fertilised seed material. Nitrogen (1000 lb. groundnut cake–2000 lb. Vempali); 2/3 of the above 1/3 of the above.	Yields were erratic; no definite conclusions could be drawn. In earlier stages of crop growth, intensively fertilised Seed appeared better, but later no differences could be noticed.	
	1943—44 to 1946—47	Variety Co. 419 : Graded dose of nitrogen with groundnut cake, with and without farmyard manure as basal dressing. Dose of Nitrogen, 0,50, 100, 150, 200 and 250 lb. per acre.	In the first year, 250 lb. N recorded highest yield but was statistically on a par with 200 lb. and 150 lb. nitrogen doses. Next two years, no significant differences. Crops in higher nitrogen plots suffered by lodging. The dose of 100 lb. Nitrogen/acre was judged best on economic grounds.	In the first year treated as bulk, due to lodging. *Second year :* 250N, 150N, 200N, 100N, 50 N, O–N. *Third year :* 100 N, 150 N, 50 N, 200 N, 250 N. O–N. *Fourth year :* Not significant.
Anakapalle	1934—35 to 1935—36	Variety Co. 213 : Molasses as manure : Basal dressing of farmyard manure at 20 cartloads; 26 lb. as nitrogen as Ammonium sulphate, groundnut cake, pillipesara, molasses to supply 26, 52, 78 lb. Nitrogen.	26 lb. Nitrogen in the form of Ammonium sulphate was superior to others. Other treatments under one bar. Molasses as manure is as good as cake in yield and quality.	Ammonium sulphate is superior to groundnut cake, and the latter superior to molasses.

APPENDIX I—*(Continued)*.

Station	Year	Manure Treatments	Results	Remarks
	1945—46	Variety Co. 419: Salvaged ammonium nitrate: Two levels of nitrogen: 100 lb. and 200 lb. Four forms of Nitrogen: Ammonium sulphate, groundnut cake, ammonium nitrate and mixture of groundnut cake and ammonium sulphate, to supply nitrogen in 2: 1 ratio.	Yield differences not significant. Ammonium nitrate ranked last in the order of yield.	200 lb. Nitrogen in form of ammonium nitrate yielded 38·73 tons against 46·63 tons when 100 lb. Nitrogen was supplied in the form of ammonium sulphate.
	1944—45 to 1947—48	Variety Co. 419: Time of application of manure. 150 lb. Nitrogen in the standard of $\frac{2}{3}$ as groundnut cake and $\frac{1}{3}$ as ammonium sulphate. Four times of application (1) all at planting, all at 2 months after planting, (3) all at 4 months after planting (4) half at planting and half at trenching.		
	1947—48 to 1249—50	Variety Co. 419: Three levels of nitrogenous manure 100, 150, 200 lb. N/acre in combination with 0, 50, 100 lb. P_2O_5.		

	1949—50 to 1950—51	Variety Co. 419: Forms of manure S, viz., 150 lb. N in the form of (1) all as groundnut cake (2) all as ammonium sulphate, (3) groundnut cake and ammonium sulphate in 1: 2 proportion on Nitrogen basis, (4) groundnut cake and ammonium sulphate in 1: 2 proportion, (5) groundnut cake and ammonium sulphate in 1: 3 proportion (6) groundnut cake and ammonium sulphate in 2: 1 proportion, (7) Groundnut cake and ammonium sulphate in 3: 1 proportion (8) groundnut cake and ammonium sulphate in 3: 2 proportion.		
	1949—50 to 1950—51	Variety Co. 419: Compost Experiment: 250 lb. N in the form of compost or farmyard manure compared with No manure. Plots receiving same manurial treatment for rotational crops also.	Yield differences not significant in the first year. Significant in the second year when sugarcane followed paddy in the same treatmental plots.	Due to cumulative effect, the treatment differences are significant in second year.
Samalkot	1902—03 to 1905—06	Farmyard manure and castor cake compared.	Yield was more when Nitrogen was applied as cake than as farmyard manure, even though total nitrogen was more in farmyard manure.	Juice quality was better under farmyard manure than under cake.
	1909—10 to 1911—12	10 tons farmyard manure compared with 10 bags castor cake.		

APPENDIX I—*(Continued)*.

Station	Year	Manure Treatments	Results	Remarks
	1912—13 to 1913—14	Variety B. 208: Cattle manure 30 tons, saffower cake 2,822 lb., gingelly cake 2,049 lb., Pungam cake, 31,815 lb., groundnut cake 1,640 lb., castor cake 2,384 lb. per acre.	Even heavy application of cattle manure was not equal to 10 bags of castor cake. Cake is definitely superior to cattle manure.	Quantities of cakes different in the two years.
	1914—15 to 1918—19	Variety J. 247: Castor cake 1,640 lb., castor cake 1,230 lb., cattle manure 10 tons.	Combination of cattle manure and cake not superior to cake alone.	
	1919—20 to 1922—23	Variety J. 247: Castor cake 3,280 lb., fish guano 3,280 lb.	Use of fish guano as substitute for castor cake on average for four years amounted to 57 lb. jaggery.	
	1927—28 to 1932—33	Purple Mauritius: Castor cake 1,640 lb., Castor cake 547 lb., Ammonium sulphate 522 lb.	In two seasons, ammonium sulphate alone or its combination with castor cake was better. In one season, ammonium sulphate alone was better. Cake alone proved inferior to combination of cake-ammonium sulphats. Dose of Nitrogen applied was 102·5 lb. per acre.	
Samalkot				Cake was applied in one dose and ammonium sulphate in two doses. Differences due to time of application were not considered.

1929—29 to 1932—33	Variety: Purple Mauritius: Groundnut cake 1,707 lb. groundnut cake 563 lb. — Ammonium sulphate 407 lb. Ammonium sulphate 610 lb.	Ammonium sulphate alone yielded highest; cake alone was poorest. In 1931-32, groundnut cake + ammonium sulphate was superior to others. In juice quality, cake alone was good with low glucose. In ammonium sulphate plots, sucrose and purity low and glucose high.	When the yields of groundnut cake series are compared to those of castor cake, they are greater-
1933—34 to 1936—37	Varieties; Co. 213, Co. 281, J. 247 and Purple Mauritius. Dose of N: 25 lb., 50 lb., 75 lb., and 100 lb./acre.	In 1934-35 there was response to increasing dose of nitrogen; J. 247 responded best. In 1935-36 between 50, 75, 100 lb. N doses there was no significant difference in yield.	Yields in 3 years were very varying.
1937—38 to 1939—40	Varieties Co. 419, J. 247 and Purple Mauritius.	Differential responses to manures were significant. 200 lb. Nitrogen per acre yielded higher than 100 lb. N dose, but not significantly. Purple Mauritius responded better in some years than in others.	Purple Mauritius recorded low yields 1939-40 as compared to 1938–39.
	—4/10 in June — 3/10 2 months after June.	In 1938-39 yields were high but no difference between treatments. In 1939-40, yields were low and more than one application best.	Differential responses recorded. In a season of drought more than one application good.

APPENDIX I—*(Continued)*.

Station	Year	Manurial Treatments	Results	Remarks
Palur	1922—23 to 1925—26	Variety: Fiji B: 100 lb. Nitrogen in the form of groundnut cake castor cake, castor cake—ammonium sulphate, fish guano.	Differences between differet treatments not marked. Castor cake plus ammonium sulpate was better than castor cake alone.	Yields in alternate years in a particular field was higher than in another field. In the plot of poor fertility fish guano was poorest and cake plus ammonium sulphate was best.
	1925—26 to 1927—28	Fiji B. Manurial treatments: 11 100 N in the form of cake, groundnut cake, fish guano. 100 lb. N as mixture of groundnut cake—ammonium sulphate, castor cake—ammonium sulphate fish guano-ammonium sulphate. 150 lb. N as castor cake—ammonium sulphate, groundnut cake—ammonium sulphate, fish guano—ammonium sulphate. 100 lb. N in the form of castor cake—ammonium sulphate, 50 lb. P_2O_5 as bonemeal or super.	Not much difference between castor cake and groundnut cake. Combination of cake and ammonium sulphate to supply 150 N is best. Phosphate not effective.	In a field of poor fertility combination with ammonium sulphate increases yield much more than in rich soils.

1928—29 to 1932—33	Variety Fiji. B. Basal dressing of farmyard manure to supply 25 lb. N, bonemeal 1 cwt. per acre, potassium sulphate, 50 lb. per acre; treatments: 50 N as groundnut cake, 40 N as groundnut cake—10 N as ammonium sulphate, 100 N as groundnut cake, 80 N as groundnut cake—20 N as ammonium sulphate, 150 N as groundnut cake, 120 N as groundnut cake—30 N as ammonium sulphate, 200 N as groundnut cake, 160 N as groundnut cake—40 N as ammonium sulphate, 20 N as groundnut cake—80 N as ammonium sulphate, 100 N as ammonium sulphate, 75 N as groundnut cake—25 N as ammonium sulphate in one dose; groundnut cake 75 N x—25 N as ammonium sulphate in 2 doses.	200 N as cake and ammonium sulphate recorded the best yield. 200 N is significantly superior to 100 N and 50 N. Yields in respect of form of N are erratic; with 100 N dose, 60 N and 40 N seems best, but critical examination shows ammonium sulphate as best and depends on distribution of rainfall. Time of application in 3:4:3 is concluded as best.	Distribution of rainfall from year has brought out differences due to time of application of manure.
1932—33 to 1936—37	Variety Fiji. B. Treatments 9: 200 N as $NaNO_3$, 120 N as groundnut cake—80 N as $NaNO_3$, 120 N as groundnut cake—100 lb. P_2O_5, 50 lb. K_2O as pot. sulphate, 120 N as groundnut cake—80 N as ammonium sulphate —100 lb. P_2O_5—50 lb. K_2O, 200 N—100 P_2O_5—50 K_2O as pot. sulphate, 200 N as $NaNO_3$—50 lb. K_2O, 200 N+50 lb. K_2O+100 lb. P_2O_5.	Though complete manure plots recorded higher yields, they are not significant. P and K no effect on yield or quality. K even depresses yield.	

APPENDIX I—*(Continued).*

Station	Year	Manurial Treatments	Results	Remarks
Palur	1939—40	Variety: P. O. J. 2878: Treatments. O N, 75 N as ammonium sulphate, 150 N as ammonium sulphate, 75 N as groundnut cake, 150 N as groundnut cake, 37½ N as ammonium sulphate—37½ N as ammonium sulphate; 75 N as groundnut cake—75 N as ammonium sulphate.	No differences due to form of Nitrogen, though 1:1 was good. Inorganic form has recorded higher yields though not significantly. 75 N as cake=O-N, but others were superior.	Data for one year only available.
		Varietal x Manurial.	Main effects on yield were due to nitrogen, and then to varieties.	
		Varieties. Co. 349, Co. 419, POJ. 2878. Nitrogen: 0,75,150 lb. P_2O_5: 0,35,70 lb. K_2O: 0,50,100 lb.	None of the varieties responded to K or P. Co. 419 responded highest to N; K and P at different levels had no effect on yield or quality.	
	1943—44 to 1946—47	Varieties Co. 281, and Co. 349: Manurial treatments—Basal dressing of 10 tons farmyard manure and no basal dressing; Nitrogen dose 0,100, 150,200 and 250 lb. Nitrogen as groundnut cake.	No significant difference between basal and no basal dressing. Increased yields recorded with higher Nitrogen doses. More than 200 lb. Nitrogen depressed juice qua...	
Gudiyattam	1939—40 to 1941—51	Variety Co. 419: Influence of phosphate on juice quality: 5 tons of farmyard manure—100 N ⅔ as castor cake—⅓ as ammonium sulphate, 1 cwt. super to treated plots.	P_2O_5 did not bring out any effect on juice quality.	Unreplicated plot test

1945—46 to 1247—48	Variety Co. 419: Graded doses of N as groundnut cake. 0,50,150,200 and 250 lb. N.	250 N recorded highest yield. Graded decrease with lower N doses Jaggery recovery highest in 50 lb. N and keeping quality better than in higher N plots.
1948—49 to 1950—51	Variety Co. 419: Nitrogen in relation to Phosphorus. Two doses of N: 200 and 250 lb./acre. Three doses of P_2O_5: 0,50,100 lb./acre.	P_2O_5 did not influence yield or quality.

APPENDIX II.

Response to Manure in Relation to Rainfall.

Station	Year	Season	Rainy days	Rainfall in inches	Variety	Dose of Nitrogen lb/acre	Yield/ acre	Response to manure	Remarks
Anakapalle	1933-34	Hot weather	12	7·72	P.O.J. 2878	25		No increased yield over increased nitrogen.	Rains in hot weather heavy.
		South-West Monsoon	38	25·72		50			South-West monsoon fairly distributed.
		North-East Monsoon	19	12·85		75			
			69	46·29		100			

APPENDIX II—*(Continued).*

Station	Year	Season	Rainy days	Rainfall in inches	Variety	Dose of Nitrogen lb/acre	Yield/ acre	Response to manure	Remarks
	1934–35	Hot weather	4	0·80	,,	25		Response to manurial dose good.	South-West monsoon copious.
		South-West Monsoon	38	26.86		50			
		North-East Monsoon	16	7-12					
			58	34·78		100			
	1935–36	Hot weather	2	0·55	,,	25		Little response to manure.	Showers in South-West Monsoon inadequate. Far end depression in yield indicates insufficiency of water.
		South-West Monsoon	32	14·93		50			
		North-East Monsoon	11	8·18		75			
			46	23·66		100			
	1944–46	Hot weather	20	7·38	Co.419	0	35·34	Increased yield with higher dose of Nitrogen.	Good hot weather rains followed by good showers in June in South-West monsoon.
						50	44·75		
		South-West				100	52·48		
		Monsoon	48	19·34		150	54·19		
		North-East				200	55·13		
		Monsoon	20	16·16		250	54·46		
			88	42·88					

	1946–47	Hot weather	11	2·29	Co.419	0	39·94	Response to manure not much. Yield differences not significant.	Deficient rainfall in hot weather and belated rainfall by August in South-West Monsoon.
						50	49·96		
		South-West				100	49·09		
		Monsoon	60	15·89		150	45·75		
		North-East				200	47·21		
		Monsoon	16	6·55		250	45·04		
			87	24·73					
Samalkot	1937–38	Hot weather	14	14·37	,,	50	56·74	Yields of 200 N and 150 N under one bar; 100 N and 150 N under one bar. 60 N inferior to others.	Beneficial rainfall in hot weather; South-West Monsoon set in early and not well distributed.
		South-West				100	66·85		
		Monsoon	41	17·74		150	70·04		
		North-East				200	71·78		
		Monsoon	15	8·59					
	1938–39	Hot weather	10	5·99	,,	100	64·96	Yield differences not significant.	Hot weather rains poor and North-East Monsoon good. Distribution of rainfall in South-West Monsoon was good.
		South-West							
		Monsoon	48	22·47		150	63·43		
		North-East							
		Monsoon	17	17·82		200	63·14		
	1939–40	Hot weather	5	2·33	,,	100	62·5	Differences in yield not significant.	Poor hot weather rains. Late receipt of South-West Monsoon showers with uneven distribution.
		South-West							
		Monsoon	40	22·52		150	62·0		
		North-East							
		Monsoon	24	30·30		200	67·2		
Palur	1928–29	Hot weather	5	1·06	Fiji-B	50		Yield differences marked.	Rainfall poor in hot weather. South-West Monsoon brought down good showers.
		South-West				100			
		Monsoon	43	17·34					
		North-East				150			
		Monsoon	45	35·07		200			
			93	53·47					

APPENDIX II—*(Continued).*

Station	Year	Season	Rainy days	Rainfall in inches	Nariety	Dose of Nitrogen lb/acre	Yield/ acre	Response to manure	Remarks
	1929–30	Hot weather	7	1·22	,,	50			Rainfall in hot weather period poor. South-West Monsoon broke out early but there was drought in July.
		South-West Monsoon	37	13·81		100			
		North-East Monsoon	46	34·30		150			
			90	49·33					
	1930–31	Hot weather	9	11·73	Fiji-B	50		150 N and 200 N are significantly superior to 50 N.	Hot weather heavy showers in one day. South-West Monsoon ill-distributed. After June there was drought till middle of August.
		South-West Monsoon	31	12·69		100			
		North-East Monsoon	51	34·26		150			
			91	58 68		200			
	1931–32	Hot weather	7	6·69		50		Increased response to higher dosage of Nitrogen.	Poor distribution of rainfall in June-July as compared to previous season. Inadequate and intermittent showers in South-West Monsoon Heavy rainfall in North-East monsoon.
		South-West Monsoon	25	11·45		100			
		North-East Monsoon	48	49·51		150			
						200			

1932–33	Hot weather	7	5·42		50		Yield differences significant.	Hot weather recorded in May. South-West Monsoon brought down less rainfall than in 1931–32. Comparatively low North-East Monsoon but distribution good from September to November.
	South-West Monsoon	32	11·05		100			
	North-East Monsoon	50	29·49		150			
		89	45·96		200			
1943–44	Hot weather	15	32·93	Co. 281	0	17·00	There is response to increased dose of Nitrogen. Exception in O-N; the differences are not significant.	Cyclone in Summer of 1943. South-West Monsoon started early in July, but drought again continued upto August.
	South-West Monsoon	23	15·97		100	37·45		
	North-East Monsoon	40	28·85	,,	150	34·60		
		78	77·75		200			
					250			
1944–46	Hot weather	18	9·48	,,	0	22·4	The increase in yield is not marked.	Summer showers in June. Continued drought till end of August.
	South-West Monsoon	17	8·69		100	21·95		
	North-East Monsoon	41	38·32		150	31·5		
					200	31·8		
		76	56·49		250			

APPENDIX II—*(Continued).*

Station	Year	Season	Rainy days	Rainfall in inches	Variety	Dose of Nitrogen lb/acre	Yield/ acre	Response to manure	Remarks
	1945–47	Hot weather	6	3·84		0	12·0	There is increase in yield with higher dose of Nitrogen. Average yields are low, even with higher dose of Nitrogen.	Drought in Summer. South-West Monsoon low but well distributed. Drought again in North-East Monsoon period from November.
		South-West Monsoon	17	8·41		100	19·0		
		North-East Monsoon	16	23·23		150	22·1		
						200	25·7		
			39	35·48		250	26·7		
	1946–47	Hot weather	9	4·07	,,	0	21·40	There is response to manuring upto 150 Nitrogen. Beyond this dose, no significant increase in yield.	Rainfall in summer was fair. Rainfall in South-West Monsoon was good and well distributed. Flood in North-East Monsoon.
		South-West Monsoon	30	16·29	,,	100	29·50		
		North-East Monsoon	60	67·85	,,	150	34·90		
						200	37·60		
						250	38·70		
Gudiyattam	1945–46	Hot weather	8	2·77	Co. 419	0	24·77	O.N. and 50 N significantly inferior. 100 N to 250 N under one bar.	Rainfall in South West Monsoon was not well distributed. It fell mostly in August.
		South-West Monsoon	23	15·74		50	30·75		
		North-East Monsoon	21	7·95		100	45·09		
						150	43·86		
						200	50·30		
						250	49·77		

1946–47	Hot weather	·8	5·54		0	20 38	Yields under 200 N ann 250 N under one bar. O.N. to 200 N significantly different.	Good showers in April May of hot weather. South-West Monsoon well distributed though not heavy.
	South-West Monsoon	35	12·87		50	32·67		
	North-East Monsoon	51	30·93		100	42·78		
					150	48·99		
		94	49·34		200	54·78		
					250	57·11		
1947–48	Hot weather	9	2·77	,,	0	15·23	Yield under O N, 50N and 100 N significantly different. 150 N and 200 N under one bar. 200 N and 250 N.	Total rainfall was below normal and season adverse. South-West Monsoon fair in distributed but North-East Monsoon was disappointing.
	South-West Monsoon	23	11·45		50	21·24		
	North-East Monsoon	17	8·14		100	30·61		
					150	38·28		
		49	22·36		200	38·69		
					250	41·81		