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Long term effect of nitrogen fertilization on yield and soil fertility status of rainfed cotton under vertisols track of Southern district

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Abstract
A field experiment was conducted in the Agricultural Research Station, Kovilpatti under dryland situation from 2011-'19 to find out the long term effect of nutrient and combined effect of organic and inorganic nutrients on crop yield and soil fertility status in cotton crop. This experiment was conducted in randomized block design replicated thrice under rainfed situation. The characteristics of the experimental soil was clay in texture and belongs to Kovilpatti Soil Series (*Typic Chromusterts*). The soil pH was towards alkaline in nature. The available nutrient status of the soil was low in available nitrogen, low to medium in available phosphorus and high in available potassium content. The treatment comprised of nine treatments. T_1 - Control, T_2 - 100% RDF (40:20:40 NPK kg ha^{-1}), T_3- 50% RDF (20:10:20 NPK kg ha^{-1}), T_4- 50% N (crop residues), T_5 -50% N (FYM), T_6 - 50% Inorganic N+ 50% organic N (crop residues) + P (50%) + K (50%), T_7 -50% inorganic N+ 50% organic N (FYM) + P (50%) + K (50%), T_8 - 100% RDF + 25 kg $ZnSO_4$ ha^{-1} and T_9 - FYM @ 12.5 ha^{-1}. The results revealed that among the different treatment schedule over the long term basis, application of 100% RDF + 25 kg $ZnSO_4$ ha^{-1} registered higher number of sympodial branches/plant (19.3 no's), number of bolls/plant (15.0 no's), boll weight (3.4 g) and seed cotton yield (1277 kg ha^{-1}), net income (Rs.24868/ha), B:C (1.76) and RWUE (3.4 kg/ha mm). Soil fertility status also has been increased over the years by the supply of nutrients through integrated plant nutrient system (IPNS) approach.

Keywords: Nutrient balance, yield attributes, economics, soil fertility and rainfed cotton

Introduction
Cotton is an important commercial crop grown throughout the world. It is the chief source of raw material to the textile industry. The growth and yield of cotton is governed by the interaction of environment with the genetic makeup of the variety or hybrid, various inputs, such as water, fertilizer, pesticides etc. Among the various inputs, fertilizers play a major role in influencing the plant growth and development of cotton. Generally major nutrients viz., N, P and K are supplied to the crop through soil and the micronutrients and growth promoting substances applied as foliar feeding. The yield of cotton is affected due to many reasons *viz.*, flower and boll shedding due to imbalance in nutrients, hormones etc., Mineral fertilizers has significant effects on crop production in the world, and are an indispensable component of today's agriculture. Estimates show that a 50 per cent increase in agricultural production is brought about through chemical fertilizers and 60% of humanity eventually owes its nutritional survival to nitrogen (N) fertilizers (Fixon and West, 2002) [4]. Unfortunately, recovery of N in soil–plant systems seldom exceeds 50 per cent of the applied N, while the remainder is lost (Abbasi *et al*., 2003) [1]. Increased recycling of plant residues, agro-industrial wastes, municipal wastes and animal manures are likely to complement the N availability and reduce dependence on mineral N fertilizers (Chambers *et al*., 2000) [3]. In addition, use of chemical fertilizers alone does not sustain productivity under continuous intensive cropping, whereas inclusion of organic materials improves soil physical properties, builds up soil fertility and increases crop yield (Yaduvanshi, 2003) [6]. Organic materials hold great promise due to their local availability as a source of multiple nutrients and ability to improve soil characteristics. For getting maximum production, farmers are in practice of using more and more chemical fertilizers. Under such a situation, it is essential to evolve and adopt a strategy of integrated nutrient management by using a judicious combination of chemical fertilizers and organic manures which may not only increase production but also improve soil health for

sustaining the productivity of *hirsutum* cotton under cotton-wheat cropping system. Deficiency of zinc has become wide spread due to this reason, response of primary nutrients is not being observed. With the application of zinc sulphate, yield was significantly improved over the recommended dose of fertilizer alone (Blaise and Singh, 2004) [2]. Keeping in view the above points, the present investigations were initiated.

Materials and Methods

This research work was initiated during the year 2011-12. Every year rabi season, cotton (KC 3) sowing has been take at the last week of September in black soil farm (Vertisols) to find out the long term effect of nutrient and combined effect of organic and inorganic nutrients on crop yield and soil fertility. The Kovilpatti region is the representative of dryland agriculture in Tamil Nadu. The depth of the black soil varies from 110 to 150cm with the infiltration rate of 0.9cm hr^{-1}. Soil develop typical cracks with at least one cm wide and reaching a depth of 50cm or more in the period of moisture stress. Considering the mechanical fraction, the soil is clayley with clay content of 46.4 to 61.2 per cent, 10.0 to 17.5 per cent silt and 12.6 to 24.5 per cent coarse sand. The soil bulk density varies from 1.21 to 1.36 kg m^{-3} with field capacity of 35 per cent and permanent wilting point of 14 per cent (Sunflower as an indicator plant). The soil has sub angular blocky structure with pH generally neutral to a tendency towards alkalinity at lower depths (7.8 to 8.2). The experiment was conducted in randomized block design (RBD) replicated thrice under rainfed condition. The treatments comprised of T_1 - Control, T_2 - 100% RDF (40:20:40 NPK kg ha^{-1}), T_3- 50% RDF (20:10:20 NPK kg ha^{-1}), T_4- 50% N (crop residues), T_5 -50% N (FYM), T_6 - 50% inorganic N+ 50% organic N (crop residues) + P (50%) + K (50%), T_7 -50% Inorganic N+ 50% organic N (FYM) + P (50%) + K (50%), T_8 -100% RDF + 25 kg $ZnSO_4$ ha^{-1} and T_9 - FYM @ 12.5 ha^{-1}. As per the treatment schedule, the full dose of inorganic fertilizers and organic manures were applied as basal application. The post harvest soil samples were collected from the experimental plots and analysed for the various soil available nutrients.

Table 1: Initial soil analysis during the year 2011

S. No.	Particulars		Value
1.	pH	:	8.13
2.	EC (dS m^{-1})	:	0.28
3.	Available nitrogen (kg ha^{-1})	:	105
4.	Available phosphorus (kg ha^{-1})	:	11.2 kg ha^{-1}
5.	Available potassium (kg ha^{-1})	:	345 kg ha^{-1}

Results and Discussion

Cotton yield and yield attributes

In long term manurial experiments, the results revealed that among the fertilizer application, the treatment received (T_8) 100% RDF + 25 kg $ZnSO_4$ ha^{-1} registered the higher number of sympodial branches/plant (19.3 no's), number of bolls/plant (15.0 no's), boll weight (3.4 g) and seed cotton yield (1277 kg ha^{-1}).

Table 2: Effect of application of organic and inorganic plant nutrient on yield attributes of rainfed cotton (KC 3) (Pooled mean)

Treatments	Plant height (cm)	No. of sympodial branches / plant	No. of bolls / plant	Boll weight (g)	seed cotton yield (kg/ha)
T_1 - Control	87.2	11.2	7.3	2.5	749
T_2 -100% RDF (40:20:40 NPK kg ha^{-1})	101.8	16.5	12.4	3.0	1137
T_3 - 50% RDF (20:10:20 NPK kg ha^{-1})	97.3	14.7	10.9	2.8	1112
T_4 - 50% N (crop residues)	93.0	15.0	11.1	2.8	1073
T_5 -50% N (FYM)	96.1	16.1	11.5	2.9	1113
T_6 - 50% inorganic N+ 50% organic N (crop residues) + P (50%) + K (50%)	96.2	15.3	11.7	3.0	1144
T_7 -.50% Inorganic N+ 50% organic N (FYM) + P (50%) + K (50%)	97.5	16.6	12.7	3.1	1177
T_8 -100% RDF + 25 kg $ZnSO_4$ ha^{-1}	98.3	19.3	15.0	3.4	1277
T_9 - FYM @ 12.5 ha^{-1}	87.2	14.6	11.0	2.8	1071
SEd	0.86	0.23	0.15	0.05	14.3
CD(0.05)	1.84	0.50	0.32	0.11	30.8

In integrated nutrient management practices, the treatment applied with (T_7) 50% Inorganic N+ 50% organic N (FYM) + P (50%) + K (50%) recorded higher yield attributes viz., sympodial branches/plant (16.6 no's), number of bolls/plant (12.7 no's), boll weight (3.1 g) and seed cotton yield (1177 kg ha^{-1}) (Table 2.). Mathur and Matish Chandra, (2005) [5] reported that the application of zinc nutrient increased the seed cotton yield, number of bolls/plant and boll weight consequently in three years in cotton-wheat cropping system.

Economics of rainfed cotton

In yield and economics of cotton (KC 3) application of **(**T_8**)** 100% RDF + 25 kg $ZnSO_4$ ha^{-1} recorded the highest net income (Rs.24868/ha), B:C (1.76) and RWUE (3.4 kg/ha mm) and it was followed by the

Table 3: Effect of application of organic and inorganic plant nutrient on yield economics of rainfed cotton (KC 3) (Pooled mean)

Treatments	Seed cotton yield (kg/ha)	Net income (Rs./ha)	B:C	RWUE (kg/ha mm)
T_1 - Control	749	6020	1.21	2.0
T_2 -100% RDF (40:20:40 NPK kg ha^{-1})	1137	19987	1.65	3.0
T_3 - 50% RDF (20:10:20 NPK kg ha^{-1})	1112	19210	1.61	2.9
T_4 - 50% N (crop residues)	1073	17037	1.55	2.8
T_5 -50% N (FYM)	1113	19770	1.66	2.9
T_6 - 50% inorganic N+ 50% organic N (crop residues) + P (50%) + K (50%)	1144	20656	1.68	2.9
T_7 -.50% Inorganic N+ 50% organic N (FYM) + P (50%) + K (50%)	1177	21614	1.69	3.1
T_8 -100% RDF + 25 kg $ZnSO_4$ ha^{-1}	1277	24868	1.76	3.4

T_9 - FYM @ 12.5 ha^{-1}	1071	14981	1.47	2.9
SEd	14.3			
CD(0.05)	30.8			

Treatment 50% Inorganic N+ 50% organic N (FYM) + P (50%) + K (50%) (T_7) which receives net income (Rs.1177/ha), B:C (1.69) and RWUE (3.1 kg/ha mm) (Table 3.).

Post harvest soil nutrient status

Regarding soil fertility status, the application of inorganic fertilizers *viz.*, (T_8) 100% RDF + 25 kg $ZnSO_4$ ha^{-1} recorded the highest soil available nitrogen (145 kg ha^{-1}), available phosphorus (17.3 kg ha^{-1}) and available potassium (482 kg ha^{-1}) and followed by combined application of 50% inorganic N+ 50% organic N (FYM) + P (50%) + K (50%) registered higher soil available nitrogen (140 kg ha^{-1}), available phosphorus (17.1 kg ha^{-1}) and available potassium (458 kg ha^{-1}).

Table 4: Effect of application of organic and inorganic plant nutrient on soil fertility status of rainfed cotton (KC 3). (Pooled mean)

Treatments	pH	EC (dSm^{-1})	Available Nitrogen (kg ha^{-1})	Available Phosphorus (kg/ha)	Available Potassium (kg ha^{-1})	Organic Carbon (g kg^{-1})
T_1 - Control	8.18	0.27	113	10.9	397	2.0
T_2 -100% RDF (40:20:40 NPK kg ha^{-1})	8.19	0.25	134	16.0	455	2.6
T_3 - 50% RDF (20:10:20 NPK kg ha^{-1})	8.18	0.24	127	15.2	447	2.8
T_4 - 50% N (crop residues)	8.18	0.28	122	14.9	438	3.2
T_5 -50% N (FYM)	8.10	0.26	129	16.4	443	3.3
T_6 - 50% inorganic N+ 50% organic N (crop residues) + P (50%) + K (50%)	8.17	0.28	136	16.8	451	3.1
T_7 -.50% Inorganic N+ 50% organic N (FYM) + P (50%) + K (50%)	8.14	0.24	140	17.1	458	3.0
T_8 -100% RDF + 25 kg $ZnSO_4$ ha^{-1}	8.16	0.28	145	17.3	482	2.9
T_9 - FYM @ 12.5 ha^{-1}	8.04	0.29	128	15.6	426	3.5
SEd	0.13	0.01	1.9	0.25	6.6	0.04
CD(0.05)	NS	NS	4.2	0.53	14.2	0.09

In case of application of organic plant nutrients, the treatment received 50% N (FYM) (T_5) registered the highest soil available nitrogen (129 kg ha^{-1}), available phosphorus (16.4 kg ha^{-1}) and available potassium (443 kg ha^{-1}) (Table 4.). It might be due to higher soil nitrogen resulted from combined application of organic and inorganic sources which increased bacterial population leading to better nodulation and mineralization of organic nitrogen with phosphorus application. Amending soil with organic matter helps in increasing the phosphorus content in soil solution through mineralization of organic phosphorus and solubilization of phosphorus significantly improved the available phosphorus content in post harvest soil. Build up of available phosphorus with phosphorus application can be attributed to an increase in the available pool of soil phosphorus after satisfying the phosphorus fixation capacity and other chemical reactions. The build up of potassium mainly due to beneficial effect of organic manures on reduction of potassium fixation, releasing potassium to the available pool of the soil.

In organic carbon status, application of FYM @ 12.5 ha^{-1} recorded the highest organic carbon content (3.5 g kg^{-1}). It might be due to build up of microbial biomass in the organic residues and addition of substrate carbon, which stimulates the indigenous soil microbes. Besides, the primary sources are also to proliferate the microbial growth.

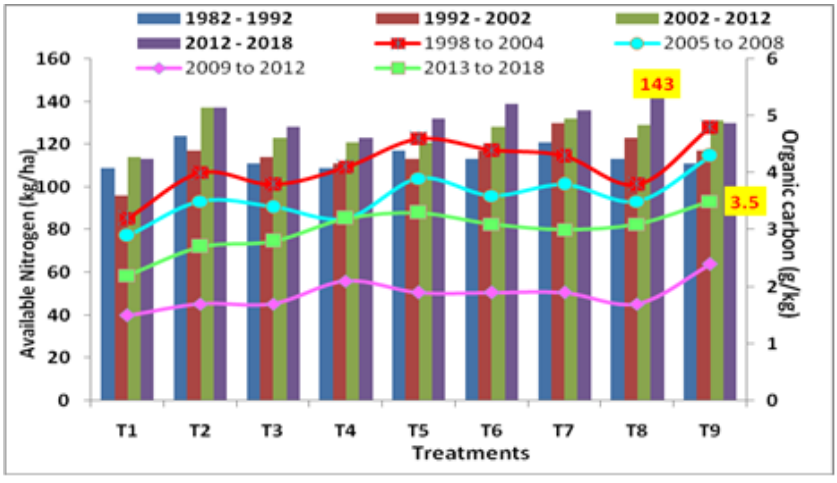

Fig 1: Soil buildup of available nitrogen (kg/ha) and organic carbon (g/kg) over the years (1982 - 2018)

There is a build up of soil available nitrogen (From 80kg to 143 kg/ha) and organic carbon (1.5g to 3.5g/kg) over the years when applied with combined application of organic and inorganic plant nutrients in the rainfed deep black soil (Fig 1.).

Soil nutrient balance status

In permanent manurial experiments, application of various combination of nutrient schedule for the cotton crop in deep black soil over the years, there is a positive nitrogen and phosphorus balance in all the treatments (Fig 2.).

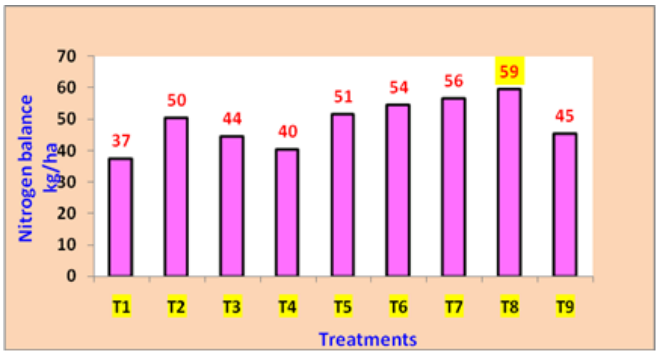

Fig 2: Soil available nitrogen balance in long term experiment under vertisols condition

It might be due to higher soil nitrogen resulted from combined application of organic and inorganic sources of fertilizers.

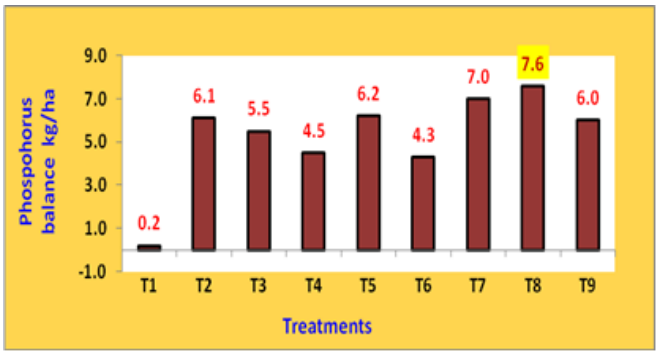

Fig 3: Soil available phosphorus balance in long term experiment under vertisols condition

With respect to phosphorus the positive balance in rainfed deep black soil, it might be due to the build up of available phosphorus in soil by release of organic acids during microbial decomposition of organic manures which help to improve native phosphorus content of soil (Fig 3.).

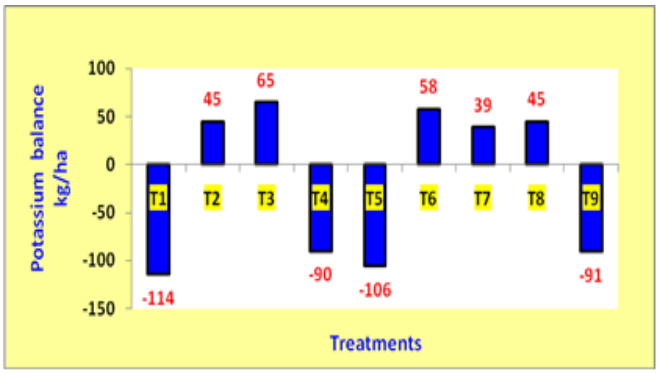

Fig 4: Soil available potassium balance in long term experiment under vertisols condition

There is a negative potassium balance is recorded in the plots applied with organic manures alone *viz.*, crop residues, farm yard manure (Fig 4.). when combined with both organic and inorganic plant nutrients showed positive balance over the years in deep black soil under rainfed condition.

Conclusion

Based on the long term effect of integrated plant nutrients system (IPNS), among the nutrient schedule, application of 100% RDF + 25 kg $ZnSO_4$ ha^{-1} performed well under the rainfed cotton in deep black soil tract of Southern Tamil Nadu.

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