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# Effect of Long Term Integrated Nutrient Management on Groundnut Productivity and Soil Fertility under Rainfed Semi-arid Alfisols of Southern India

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**ABSTRACT:** The effect of integrated nutrient management practices on groundnut (*Arachis hypogaea*) mono-cropping system productivity and soil fertility after 37 years of cropping in an undisturbed site for 1985-2021 is being studied in an Alfisols at Agricultural research station, Anantapur under long term permanent manurial trial. The experiment was conducted on an Alfisols under rainfed conditions in a randomized block design. The nine nutrient management treatments were: control (no manure and fertilizer); 100% recommended dose of NPK (20-40-40 NPK kg $ha^{-1}$); 50% recommended dose of NPK; groundnut shells @ 4 t $ha^{-1}$; FYM @ 4 t $ha^{-1}$; 50% NPK+ groundnut shells @ 4 t $ha^{-1}$; 50% NPK+ FYM @ 4 t $ha^{-1}$; 100% NPK+ $ZnSO_4$ @ 50 kg $ha^{-1}$ and FYM @ 5 t $ha^{-1}$. All the treatments were replicated thrice. Plots under 100% NPK followed by 100% NPK + $ZnSO_4$ @ 50 kg $ha^{-1}$ maintained higher pod yields (30.1 and 27.5% respectively) than control. However, integrated application of groundnut shells and FYM treatments improved the available nutrient status in soil besides sustaining the pod yields after 37 years of mono-cropping. With the exception of control and 50% NPK treatments, there was a positive nutrient balance of NPK in all integrated nutrient management treatments. The available phosphorus and soil organic carbon (SOC) content buildup was conspicuous among all the INM treatments compared to sole application of chemical fertilizers. Application of groundnut shells either solely or in combination with chemical fertilizers was as effective as FYM in terms of pod yield and carbon build up.

**Key words:** FYM, groundnut shells, integrated nutrient management**,** pod yield, rainfed, soil fertility

## Introduction

Rainfed farming plays a predominant role in Indian agriculture, it comprises about 51 per cent of country's net sown area and accounts for nearly 40 per cent of the total food production. Rainfed agriculture is complex, highly diverse and risk prone and major production system in arid, semi-arid and sub humid regions of India with annual rainfall ranged between 500-1500 mm (Singh *et al.,* 2004). However, the Alfisols are the predominant soils in southern Andhra Pradesh which supports the groundnut mono-cropping system largely by small and marginal farmers. Low rainfall, uneven distribution of rainfall and frequent droughts are the conspicuous characters of the climate in this region (Viramani *et al.,* 1991). The soils are coarse textured, shallow rooting depth, low water holding capacity, soil crusting and poor soil fertility. These soils are low in soil organic carbon (SOC), low in available N, P, K and S contents and also deficient in available Mg, Zn and B contents (Srinivasarao *et al.,* 2013). These are the prominent reasons restricting groundnut as single rainy season (*kharif*) crop with low productivity levels of about 0.7 to 0.8 Mg $ha^{-1}$.

Therefore, to sustain the crop yields and soil fertility for long term in the region requires adoption of integrated nutrient management (INM) practices for the existing cropping system is most necessary. However, the resource poor, small and marginal farmers in the region supply only the meager quantity of nutrients to soil and thus crop suffers from multi nutrient deficiencies consequently low yields (Srinivasarao *et al*., 2012). The availability of organic sources of nutrients such as crop residues, FYM are low due to many competing uses (livestock feed, fuel etc.) in the semi-arid environment. Which also exacerbated by low biomass productivity as a constraint in the region to practice INM. Yet, some crop by-products like groundnut shells (GNS) are available for use as soil amendment. With escalating cost of chemical fertilizers and also to manage the imbalanced use of inorganic fertilizers, groundnut shells are the viable alternate source for supply of plant nutrients to sustain soil health in the region (Srinivasarao *et al.,* 2013). The GNS are rich with respect to NPK and contains 1.0, 0.25 and 1.1% respectively, as compared to FYM. This GNS serves as an important component of INM system to maintain soil fertility and crop yields, especially in the major groundnut cultivated region like Anantapur district in Andhra Pradesh. In this context, the present study was conducted to evaluate the effect of 37 years of INM practices with locally available organic sources like groundnut shells and commonly used FYM in an undisturbed site on sustainability of groundnut pod yield and soil fertility of an Alfisol under rainfed conditions.

## Materials and Methods

The present investigation (*kharif* 2021) is a part of an ongoing long term (1985-2021) field experiment with groundnut mono-cropping system in progress since *kharif* 1985 at Agricultural Research Station, Ananthapuramu (14º 41' 17" N: 77º 40' 07" E) under All India Coordinated Research Project for Dryland Agriculture. The soil of the experimental field is alfisols belonging to vayalpadu soil series (hyperthermic, Typic Rhodustalfs) with sandy loam texture and about 30 cm shallow soil depth. The geographical position of Anantapur is in the middle of peninsula renders it the driest part. The average annual rainfall is 546 mm. The site experiences mean annual minimum and maximum temperature of 21.5 and 34.0 ºC, respectively. The rainfall distribution prevailed during the crop growth period is presented in Figure 1. The initial surface soil (0-20 cm) analyses of the experimental site had pH 6.6, EC 0.06 ds m-1-, organic carbon 0.25%, available N, $P_2O_5$, and $K_2O$ of 139, 21 and 155 kg ha$^{-1}$, zinc 1.03 ppm, respectively. There were nine treatments which are combination of organic and inorganic sources and tested for their effect on soil properties and yield over long term. The treatments include, $T_1$: Control (no fertilizer and manures), $T_2$: Recommended fertilizer dose (20-40-40 NPK kg ha$^{-1}$), $T_3$: Half recommended fertilizer dose (10-20-20 NPK kg ha$^{-1}$), $T_4$: Groundnut shells @ 4 t ha$^{-1}$, $T_5$: FYM @ 4 t ha$^{-1}$, $T_6$: Half recommended fertilizer dose + groundnut shells @ 4 t ha$^{-1}$, $T_7$: Half recommended fertilizer dose + FYM @ 4 t ha$^{-1}$ $T_8$: Recommended fertilizer dose + $ZnSO_4$ @ 50 kg ha$^{-1}$ (once in 3 years), $T_9$: FYM @ 5 t ha$^{-1}$. Each treatment was replicated thrice in a randomized block design. The sources of inorganic N, P and K were urea, single super-phosphate and muriate of potash. Groundnut shells (1.2% N) and farm yard manure (0.65% N) was incorporated treatment wise in the soil 15 days before sowing of the groundnut. In general, the groundnut crop was sown on the onset of monsoon with sufficient moisture. The crop was harvested at maturity and yield data were recorded. The soil samples from 0-20 cm depth were collected after harvest of groundnut in the 37$^{th}$ cropping year (2021-22) and were analyzed for organic carbon (Walkly and black method), available N by alkaline permanganate method, available P (olsen extract) available K (Ammonium acetate extract).

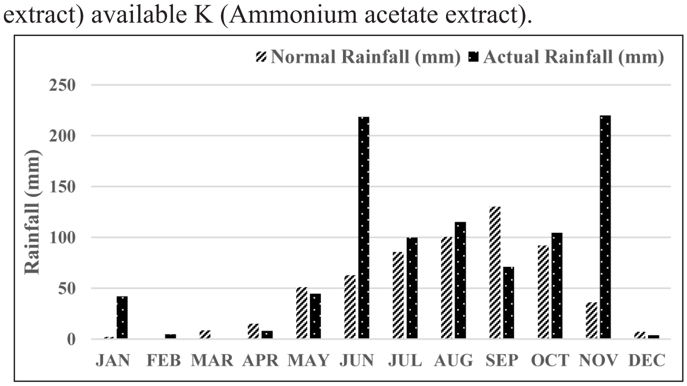


**Fig. 1: Mean monthly rainfall during the crop growth period, 2021**

## Results and Discussion

### Crop productivity

The pod yield of groundnut in different treatments since 1985 to 2021 is presented in Figure 2. The results of the 37 cropping cycles of groundnut indicated that, the long term application of inorganic fertilizers and organic amendments, solely and in combination significantly influenced the productivity of groundnut over years. The results presented in Table 1 pertaining to pod and haulm yield of groundnut obtained during the year 2021 revealed that, highest pod yield (956 kg ha$^{-1}$) and haulm yield (1911 kg ha$^{-1}$) was recorded in half recommended NPK + FYM @ 4 t ha$^{-1}$ and the lowest pod yield (643 kg ha$^{-1}$) in control plot and lowest haulm yield was recorded in groundnut shells @ 4 t ha$^{-1}$.

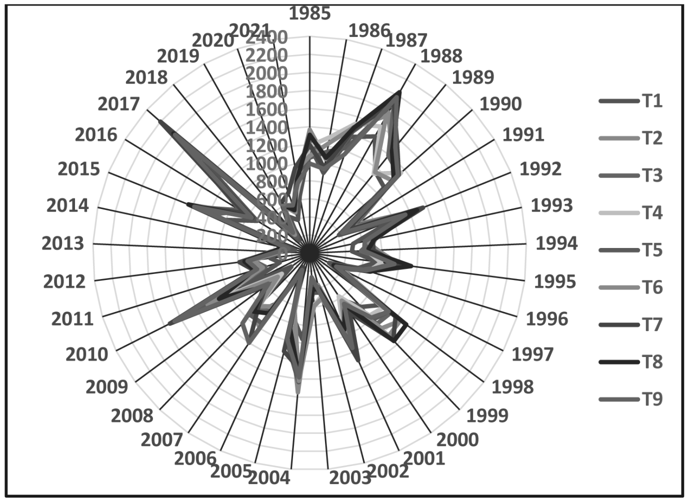


**Fig. 2: Groundnut pod yield as influenced by INM practices over 37 (1985-2021) years**

(Source: Annual Report, AICRPDA. 2021, ARS, Ananthapuramu)

However, the long term (37 year) impact of integrated nutrient management practices on the trend of groundnut yield obtained revealed that, 100% NPK application increased the highest pod yield (30.1%) over control followed by 100% NPK+ $ZnSO_4$ @ 50 kg ha$^{-1}$ (27.5%), FYM @ 4 t ha$^{-1}$ (24.9%), FYM @ 5 t ha$^{-1}$(24.3%), 50% NPK + groundnut shells @ 4 t ha$^{-1}$ (22.3%), 50% NPK (20.9%), 50% NPK + FYM @ 4 t ha$^{-1}$ (19.5%) and least over the control was groundnut shells @ 4 t ha$^{-1}$ (18.1%). But, response of the practices over years exhibited declining trend mainly due to variability in rainfall during crop growth period, imbalanced nutrient supply due to sole organic sources and poor soil fertility under rainfed hot- arid conditions. The similar results were also reported by Tomar *et al*. (2018) in inceptisol under pearl millet- mustard cropping system.

**Table 1: Effect of integrated nutrient management on yield (kg ha$^{-1}$) of groundnut after 37 years**

| Treatment | Initial pod yield 1985 | Haul yield 2021 | Pod yield 2021 | Mean pod yield (37 years) | Pod yield increase over control (%) |
|---|---|---|---|---|---|
| | (kg ha$^{-1}$) | | | | |
| T1 | 1186 | 1490 | 643 | 708 | -- |
| T2 | 1367 | 1755 | 805 | 921 | 30.1 |
| T3 | 1288 | 1843 | 757 | 856 | 20.9 |
| T4 | 1187 | 1285 | 746 | 836 | 18.1 |
| T5 | 1058 | 1610 | 877 | 884 | 24.9 |
| T6 | 1077 | 1757 | 923 | 866 | 22.3 |
| T7 | 1197 | 1911 | 956 | 846 | 19.5 |
| T8 | 1309 | 1654 | 827 | 903 | 27.5 |
| T9 | 991 | 1575 | 787 | 880 | 24.3 |
| SE m ± | -- | 100.2 | 50.1 | -- | -- |
| CD at 5% | 84 | 289.7 | 144.8 | -- | -- |

The results of the present long term experiment clearly indicate that, application of 100% recommended NPK in conjunction with organic and inorganic sources could achieve higher pod yield over control. The beneficial effect of integrated use of manures and fertilizers in terms of increased nutrient availability, increased soil moisture due to organic sources in soil, also due to conversion from unavailable to available form of organic sources and also due to improved physical, chemical and biological soil environment. These results are in conformity with the findings of Sankar *et al*. (2010). Thus the results of the long term impact of INM practices on productivity of groundnut yield clearly indicate that, application of organic and inorganic sources is necessary for sustaining the agronomic crop productivity over years. The similar results also reported by Srinivasarao *et al*. (2012) in groundnut based production system in rainfed alfisols.



### Soil fertility

The annual application of organic and inorganic fertilizers in combination over years had no significant effect on soil reaction and electrical conductivity of soil (Table 2). However, there is slight increase in soil pH in recommended fertilizer and FYM applied plots. The electrical conductivity reduced from the initial level probably due to leaching of salts over years. The magnitude of change with respect to soil reaction and electrical conductivity is very minute indicating beneficial effect of integrated nutrient management practices over long period.

**Table 2: Physico-chemical properties of soil after harvest of *kharif* groundnut during 2021**

| Treatment | Soil properties | | | OC (%) increase / decrease over years |
|---|---|---|---|---|
| | pH | EC (dS m$^{-1}$) | OC (%) | |
| Initial (1985) | 6.6 | 0.06 | 0.25 | -- |
| T1 | 6.2 | 0.01 | 0.22 | -12.0 |
| T2 | 6.7 | 0.01 | 0.25 | 0.0 |
| T3 | 6.3 | 0.02 | 0.24 | -4.0 |
| T4 | 6.5 | 0.01 | 0.27 | 8.0 |
| T5 | 6.7 | 0.01 | 0.29 | 16.0 |
| T6 | 6.5 | 0.01 | 0.33 | 32.0 |
| T7 | 6.4 | 0.01 | 0.24 | -4.0 |
| T8 | 6.2 | 0.01 | 0.28 | 12.0 |
| T9 | 6.2 | 0.01 | 0.24 | -4.0 |
| SE m ± | 0.44 | 0.01 | 0.19 | -- |
| CD at 5% | NS | NS | NS | -- |

Long term application of two levels of recommended fertilizers and organic amendments solely and conjointly had significant effect on organic carbon. Although increase in organic carbon content was marginal over years as presented in the Figure 3. The highest organic carbon (%) was recorded with respect to 50% NPK + groundnut shells @ 4 t ha$^{-1}$ followed by FYM @ 4 t ha$^{-1}$, 100% NPK+ $ZnSO_4$ @ 50 kg ha$^{-1}$ and groundnut shells @ 4 t ha$^{-1}$ in contrast the negative balance was also recorded in control treatment followed by 50% NPK, 50% NPK + FYM @ 4 t ha$^{-1}$ and FYM @ 5 t ha$^{-1}$. The negative balance is obviously due to inadequate supply of organic matter to soil. However, the marginal increase was observed in the treatments where organic and inorganic sources were used to supply the balanced nutrition clearly indicating the beneficial effect of integrated nutrient management practices on carbon storage in the soil. Continuous application of inorganic fertilizers as recommended or half recommended dose as supplementary nutrients along with organic amendments resulted in possible increase in the carbon content in the respective treatments. The similar results in long term integrated nutrient management induced soil organic carbon content was also reported earlier in sorghum – wheat (Datta *et al.,* 2018), rice-rice (Anantha *et al.,* 2018) and groundnut mono cropping systems by Srinivasrao *et al*. (2012).

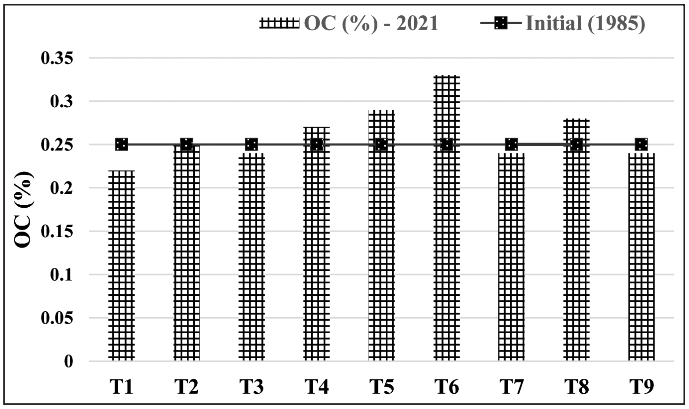


**Fig. 3: Effect of different INM practices on organic carbon (%) storage in soil over years**

The available nitrogen content after the harvest of *kharif* 2021 ranged from 150 to 189 kg ha$^{-1}$, this was high in 50% NPK + FYM @ 4 t ha$^{-1}$ and all treatments showed higher than control (Table 3). Over 37 years of cropping 50% NPK + FYM @ 4 t ha$^{-1}$ maintained higher level of nitrogen content compared to all other treatments. This indicates that, the integrated application of organic and inorganic fertilizers at different levels helped to maintain the nitrogen content in soil. The similar results were also reported by Thakur *et al*. (2011) in soybean - wheat cropping system. The available phosphorus content in soil was ranged from 23 to 62 kg ha$^{-1}$ during 2021. However, the perusal of data in Table 2 indicates that, 50% NPK + FYM @ 4 t ha$^{-1}$ showed highest P and lowest in groundnut shells @ 4 t ha$^{-1}$. The marginal increase in the status of P was recorded in all the treatment combination except groundnut shells @ 4 t ha$^{-1}$. This indicates that the uptake of P by plants was much facilitated by groundnut shells @ 4 t ha$^{-1}$ in soil compared to other treatments. The inorganic fertilizers in combination with organics followed by sole application of inorganic fertilizers influenced the strong P build up in soil. The results are in line with the findings of Dwivedi *et al*. (2007) in soybean – wheat system in vertisols of central India.

**Table 3: Available major nutrient status in soil under undisturbed site after harvest of *kharif* groundnut - 2021**

| Treatments | Available nutrient content after harvest *kharif* 2021 (kg ha$^{-1}$) | | | Apparent nutrient content variation as compared to initial values (kg ha$^{-1}$) | | | Nutrient content increase /decrease (kg ha$^{-1}$ yr$^{-1}$) | | | Zinc content in soil (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | N | P | K | N | P | K | Zn |
| Initial (1985) | 139 | 21 | 155 | -- | -- | -- | -- | -- | -- | 1.03 |
| T1 | 150 | 38 | 83 | 11 | 17 | -72 | 0.3 | 0.5 | -1.9 | 1.0 |
| T2 | 169 | 38 | 235 | 30 | 17 | 80 | 0.8 | 0.5 | 2.2 | 1.0 |
| T3 | 163 | 47 | 130 | 24 | 26 | -25 | 0.6 | 0.7 | -0.7 | 1.0 |
| T4 | 162 | 23 | 173 | 23 | 2 | 18 | 0.6 | 0.1 | 0.5 | 1.9 |
| T5 | 170 | 29 | 179 | 31 | 8 | 24 | 0.8 | 0.2 | 0.6 | 1.8 |
| T6 | 179 | 48 | 217 | 40 | 27 | 62 | 1.1 | 0.7 | 1.7 | 1.8 |
| T7 | 189 | 62 | 229 | 50 | 41 | 74 | 1.4 | 1.1 | 2.0 | 1.7 |
| T8 | 175 | 39 | 217 | 36 | 18 | 62 | 1.0 | 0.5 | 1.7 | 1.7 |
| T9 | 187 | 29 | 200 | 48 | 8 | 45 | 1.3 | 0.2 | 1.2 | 1.2 |
| SE m ± | 111.6 | 12.8 | 118.0 | -- | -- | -- | -- | -- | -- | -- |
| CD at 5% | NS | 4.41 | NS | -- | -- | -- | -- | -- | -- | -- |

The available potassium content in soil after harvest of *kharif* 2021 ranged from 83 to 235 kg ha$^{-1}$ (Table 3). The highest potassium content in soil was recorded over years with application of 100% NPK followed by 50% NPK + FYM @ 4 t ha$^{-1}$, 50% NPK + groundnut shells @ 4 t ha$^{-1}$ and 100% NPK + ZnSO4 @ 50 kg ha$^{-1}$ as compared to the initial values. The negative potassium balance was also recorded over years with the maximum decline (1.9 kg ha$^{-1}$ yr$^{-1}$) per year in control followed by application of 50% NPK. The magnitude of potassium buildup increased with increasing level of combined application of organic and inorganic sources of nutrients. This clearly indicates the importance of conjunctive use of organic and inorganic sources for the balanced K maintenance in soil. These findings are in conformity with the results of Tomar *et al*. (2018) under long term pearl millet - mustard cropping system in inceptisols.

## Conclusion

Balanced fertilization with inorganic and organic amendments improved the carbon content even under adverse climatic (erratic rainfall, high temperatures in summer) and soil (sandy and low clay alfisols) conditions. Application of 100% NPK also maintained the yield levels as required nutrients for each crop was supplied. However, the soil data pertaining to present investigation for long term support the conclusion that, integrated application of recommended NPK along with adequate amount of organics such as locally available groundnut shells or FYM improved the soil organic carbon storage, available nutrients and thereby soil quality and fertility. Thus, integrated nutrient management practices sustain the yield level of groundnut mono-cropping system and soil fertility for long term in alfisol under rainfed agro-ecosystem.

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