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# Assessment of Chemical and Biological Parameters in Sorghum-Wheat Cropping Sequence under Long Term Fertilization - A Review

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## Abstract

Continuous addition of chemical fertilizers poses problems like toxicity due to high amounts of salts as residues of fertilizer and deterioration of the physico-chemical properties. Organic manure ameliorates this problem as organic matter helps in increasing adsorptive power of soil for cations and anions particularly phosphate and nitrate. The continuous use of chemical fertilizers over a long period may cause imbalance in the microbial population and there by indirectly affect the biological properties. The microbial biomass, which is the total sum of all microorganisms present in soil, serves as a temporary sink for nutrients including nitrogen and can be considered as an index of soil fertility. Soil harbours dynamic population of microorganisms, which play major role in decomposition of organic matter and transformation of plant nutrients. The availability of organically bounded nitrogen through transformation in soil to the plant mainly depends on the population of microorganisms, which may be influenced by the application of inorganic fertilizers and organic manure.

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Labile carbon
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## Introduction

Long term fertilization in cropping system plays a key role in maintaining soil physico-chemical and biological conditions. Inorganic fertilization to the soil results in decline in organic carbon content of soil which negatively affects the biological activity in the soil, especially beneficial microbial population. Soil beneficial microorganisms and organic matter content are important for slow release of nutrients in the soil which is essential for crop plants. Organic input to the soil is known to improve soil organic carbon and microbial population. Either alone or in combination of organics with inorganics may help in the revival of soil fertility status thus favouring the crop growth and yield. The present review highlights the chemical and biological parameters in sorghum-wheat cropping sequence under long term fertilization.

## Assessment of chemical parameters in sorghum-wheat cropping system under long term fertilization

### Organic carbon and labile carbon

Verma et al. (1987) reported that the decline in organic carbon content in soil as a result of continuous intensive rice-wheat rotation without adding organic matter to the soil. However, combined use of organics and inorganics increased the organic carbon status of soil. Kukreja (1991) studied and observed that application of FYM enhanced the organic carbon and total nitrogen. Bhandari et al. (1992) observed that combined use of organics and inorganics increased organic carbon status of soil.

Gupta et al. (1992) reported an increase in organic carbon content of soil with application of FYM and 120 kg N per ha. Bhardwaj et al. (1994) reported continuous cropping without fertilization led to the depletion of organic carbon and available NPK. Whereas, continuous fertilization had beneficial effect on organic carbon status. Blair et al. (1995) reported that ploughing and cropping of a pasture soil results in a rapid decrease in carbon particularly the more labile fractions.

Tiwari et al. (1995) noted decrease in organic carbon content with profile depth. The decrease was more evident in the 15-30 cm soil depth because most organic carbon residues remained in the plough layer. Kamalakumari and Singaram (1996) noticed that application of FYM and NPK continuously for 20 years in maize-cowpea-finger millet cropping sequence showed significant increase in organic carbon content of the soil. Whitebread et al. (1996) found only slight increases in total carbon following three years of residue that there was a significant increase in labile carbon.

Eak and Stewart (1998) pointed out that organic carbon did not change significantly during the time period. Ravankar et al. (1998) found that the application of 100% NPK along with 10 tonnes FYM per ha increased the organic carbon content of Vertisol. Vaidya and Gabhane (1998) showed that organic carbon status of the soil increased with increasing level of fertilizer doses after seventh cycle of sorghum-wheat cropping sequence. They also noticed that combination of fertilizers with FYM increased the organic carbon status of the soil.

Sharma et al. (2000) observed that the organic carbon content increased significantly in treatments having combined application of crop residues, FYM and fertilizer compared to fertilizer alone. Bhattacharyya et al. (2004) reported that the oxidizable soil organic carbon content was maximum in NPK + FYM treatment at 0-15 cm depth and was significantly more than all other treatments. Sharma et al. (2007) noticed that the organic carbon from the initial level of 14.8 g $kg^{-1}$, declined to 4.9 g $kg^{-1}$ in control plot and 8.4 g $kg^{-1}$ in 100% NPK plot. However, use of 100% NPK + FYM had maintained the level of organic carbon even after 31 years of cultivation.

## Total nitrogen and N-mineralization

Schimel et al. (1985) found that N-mineralization ranged from 0.9 to 1.9 % of total N and this proportion generally increased on cultivation. Consistantinides and Fownes (1994) found that Nitrogen content in the material favours net mineralization and N concentration from <1.7 to 2.0% generally causes net immobilization.

Sarkar et al. (1994) reported that the effect of rate of urea application on the loss of nitrogen on an average the magnitude of nitrogen loss was 27% of applied nitrogen at no gypsum treatment and such effect lowering down the nitrogen loss was more pronounced at higher levels of nitrogen application.

Hutchinson et al. (1995) concluded that denitrification is usually not restricted by enzyme activity but influenced by organic carbon and oxygen availability, presence of nitrogen oxides ($NO_3^-$, $NO_2^-$, NO or $N_2O$), type of crop residues, degree of decomposition, $NO_3^-$ supply and soluble carbon supply affect the amount of denitrification gases (NO, $N_2O$, $N_2$) produced.

Eak and Stewart (1998) reported that the total nitrogen did not change significantly during the time period. Dinesh and Dubey (1999) observed that the N-mineralization rates were greater during the first week and decreased with time in all treatments. On an average, the organic manure amended soil leached 156.3 mg $kg^{-1}$ more $NO_3^-$ + $NO_2^-$ than that unamended control. The net N-mineralization was however, significantly higher in soils amended with organic manures compared to the unamended control.

Mishra et al. (2001) reported that N content of the wheat straw increased markedly during 2nd to 10th week and witnessed little change thereafter during first two weeks 23.8 and 29.3 % of the total N present in the wheat straw was mineralized in case of absence and presence of green manure treatments, respectively. Then they concluded that the incorporation of wheat straw before 10 weeks of rice transplanting could overcome the problem of N-mineralization during crop growth period. Sridevi et al. (2006) observed that mineral nitrogen in the control soil increased from the initial value of 7.84 to 40.42 mg $kg^{-1}$ by the end of 90 days of incubation.

## Availability of macro-nutrients

Singh et al. (1980) registered increase of total and available N and also available K status with the continuous use of FYM under the cropping systems. Dinesh and Dubey (1999) observed that the N-mineralization rates were greater during the first week and decreased with time in all treatments. On an average, the organic manure amended soil leached 156.3 mg $kg^{-1}$ more $NO_3^-$ + $NO_2^-$ than that unamended control. The net N-mineralization was however, significantly higher in soils amended with organic manures compared to the unamended control.

Chahal et al. (1984) reported that the bajra-wheat sequence showed a cumulative use of 60 kg $P_2O_5$ per ha dose raised the available P level in soil from 17 to 28.6 kg P $ha^{-1}$. Available N and K status decreased with continuous cropping from 215 to 132 kg $ha^{-1}$ and 616 to 256 kg $ha^{-1}$ respectively. Jeevanrao and Dakhore (1994) from a long time manorial experiment on vertisols revealed on increasing in organic carbon, available NPK with the application of 30 kg $P_2O_5$ $ha^{-1}$, 30 kg $K_2O$ $ha^{-1}$ and 15 tonnes of FYM $ha^{-1}$.

Pandey et al. (1985) observed that fertilizer N alone or in combination with P and K invariably resulted in the significant increase over control showing positive balance for available N status of soil. Gupta et al. (1988) found that during wheat growing, organic carbon and available P increased up to 52 days and thereafter decreased at both the soil depth with application of FYM irrespective of levels. The available P content of the soil remained in sufficient range with the application of FYM. The available N content of the soil increased up to 20 days after FYM application and decreased thereafter at all the FYM levels.

Jayaraman (1988) concluded that application of 75 kg N per ha and green leaf manure of leuceana improved organic carbon and N content of soil as compared to N fertilizers alone. Lal and Mathur (1988) observed that the available N in soil was increased significantly in fertilizer treated plots as compared to that of FYM alone and its significant correlation was noticed with total N.

Yaduvanshi (1988) reported improvement in available P content in soil due to the application of FYM in long term fertilizer experiments, however it decreased in absence of P application. Verma and Yadav (1988) studied the effect of long term fertilization to rice –wheat sequence for seven years and observed maximum depletion in total N status of the soil in control (No Po Ko). A negative balance was reported at $N_{40}$ level. Whereas at higher level of N (80 and 120kg $ha^{-1}$), considerable build up of soil N was observed.

Jadhav (1989) reported that the total N and available P showed a positive balance under groundnut-wheat sequence whereas a negative balance was observed under sorghum-wheat cropping system. The decline in availability of K was noticed under sorghum-wheat as well as groundnut-wheat system. Swarup and Singh (1989) during long term experiment on rice and wheat grown in rotation for twenty years observed reduction in available N from initial values of 225 kg $ha^{-1}$ to 120 kg $ha^{-1}$ in untreated plots and available P also decreased from initial value.

Udaysoorian et al. (1989) during long term study observed that the continuous organic manuring for eight years significantly increased soil available K content in the surface and sub-surface layers. Lal et al. (1990) reported significant increase in total K in long term application of FYM, fertilizer and lime after 28 years. Prasad et al. (1991) observed that available S and P of soil were interrelated and their availability was increased when S and P were applied on combination.

Raghuvanshi et al. (1991) reported that total N in the soil after 2 years experiment showed a deficit of 13 kg N $ha^{-1}$ in sorghum-wheat sequence whereas nitrogen status of soil improved in legume cropping sequence. The available P showed deficit in all cropping sequences while availability of K was improved in sorghum-wheat cropping sequence. Bansal (1992) observed that the application of K and FYM alone significantly increased the available K content in soil and further build up was observed with application of 100% NPK + FYM.

Bhandari et al. (1992) also reported increased availability of P in soil with the combined use of NPK fertilizer and organic N source of rice-wheat cropping system. Gupta et al. (1992) reported favorable effect of FYM and N doses in increasing the available P at all depths under pearl millet-wheat cropping sequence. Kumar and Yadav (1993) noted that the application of K fertilizer increased availability of K over its initial value, while the treatment without K fertilizer caused its reduction. The available K status remained unaffected with the use of different levels on N or NP combinations in rice-wheat cropping sequence.

Naphade et al. (1993) reported that the application of 150% NPK fertilizer increased the available P and available K status of soil. Similarly application of FYM along with 100% NPK increased the same. Dhanorkar et al. (1994) studied that the long term application of FYM and NPK fertilizers over 20 years observed distinct build up in total K where potassium was applied. The highest total K was recorded where 56.7 kg $K_2O$ per ha was applied along with FYM.

Mathan et al. (1994) observed that the available nutrient status of the soil after harvest of crops increased significantly by the treatment urea (25 kg $ha^{-1}$) + FYM (7.5 t $ha^{-1}$). Nambiar (1994) revealed that continuous use of FYM raised available K 1.3 to 5.4 folds over control.

It was reported that application of fertilizer K to crops was found inadequate as compared with K requirement, resulting in over exploitation of native K.

Tyagi and Bhardwaj (1994) studied the effect of long term fertilizer application on the availability of P which was decreased from 47.5 to 5.8 kg $ha^{-1}$ from 0-15 cm to 75-90 cm depth respectively. The lowest available P was found in control while highest content in 150% NPK treatment. The continuous cropping without fertilization or manuring decreased the available P status of the soil. Malewar and Hasnabade (1995) reported significant increase in available NP and K with continuous application of organic and inorganic fertilizer particularly with FYM + NPK. Sheeba and Chellumuthu (1996) observed that the continuous addition of P fertilizers increased the concentration of total P in the soil. Application of 100% NPK + FYM resulted in buildup of total and available P status of soil.

Singh et al. (1996) observed that introduction of legume in cropping system increased available soil P. Dudhat et al. (1997) reported that application of FYM alone or in combination with chemical fertilizer significantly increased the residual status of available N and P in soil. Singh (1997) reported that continuous cropping with high analysis fertilizer (DAP) tended to decrease available S content of soil. N fertilizers application indicated reduced S availability in soil from initial levels of 22.5 mg $kg^{-1}$ to 17.1 mg $kg^{-1}$ after 25 cropping cycles.

Lupwayi and Haque (1998) observed that leaves of leuceana applied at an equivalent rate of 3 t dry matter per ha were significant source of N, K and Mg. They further stated that N in leuceana mineralized in soil more slowly than sesbania and to avoid leaching, erosion, volatilization or denitrification loss of N. Ravanker et al. (1998) reported that the long term application of 100% NPK dose along with 10 t FYM $ha^{-1}$ enhanced spectacularly the amount of total N and available NPK of Vertisol under sorghum-wheat sequence.

Santhy et al. (1998) reported higher available N in treatment 100% NPK + FYM due to high organic carbon content. They further reported that availability of N was increased after sorghum-wheat sequence in fertilizer treatment. Tembhare et al. (1998) reported appreciable build up of available soil P in Vertisol at optimal to super optimal (100 to 150% NPK) doses. This increase in available P becomes sharp after 12 cropping cycles and declining trend of available K even at 150% NPK.

Yadav and Kumar (1998) revealed that the continuous application of NPK fertilizer alone at 100% recommended level and their combination with FYM increased the available P in soil over the initial status. Poongothia et al. (1999) reported that the highest content being recorded for the application of S as gypsum. Application of green leaf manure increased the available S content of the soil and the effect was more marked in the presence of gypsum. Sharma et al. (2007) noticed that available nutrients (NPK) in the soil were the lowest in the control plot and the highest in the plot under super optimal NPK. Graded doses of NPK significantly increased their availability in soil. And they also reported the significant increase in available nutrient (NPK) content of the soil in the plot receiving 100% NPK.

## Exchangeable Ca and Mg

Bellakki and Badanur (1997) reported that the increasing trend of exchangeable Ca and Mg with the application of FYM. Bellaki et al. (1998) conducted long term experiment for 10 years on Typic Chromusterts and indicated increase in CEC and exchangeable Ca contents of the soil due to incorporation of different organic sources of nutrients.

Shrikanth et al. (2000) reported that the application of vermicompost Increase the exchangeable Ca and Mg content in soil. Chander et al. (2007) reported that the FYM incorporation, however resulted in to a significant and consistent increase in exchangeable Ca. and also noticed that the exchangeable Ca content at harvest decreased as compared to that observed during mid of the growth period.

## Soil reaction (pH) and electrical conductivity

Yaduvanshi et al. (1985) reported noticeable decrease in pH value as result of continuous manuring over initial value, the decline being pronounced under 100% N and 150% NPK treatments. A relatively higher soil pH under 100% NPK + FYM in comparison with 100% NPK was also recorded. Kaushal et al. (1986) reported that the pH of soil rise with depth due to corresponding increase in $CaCO_3$ and to some extent salt content in some lower layers.

Tyagi and Bhardwaj (1994) observed that the continuous use of manures and fertilizers lowered the pH slightly but with increased soil depth (0-15, 15-30, and 30-45) the pH of soil was also increased. They also reported that there is no effect on electrical conductivity. Sinha et al. (1997)

observed that the continuous use of N as urea, either alone or in combination with P and K decreased the soil pH.

Kumarswami et al. (1998) reported that continuous cropping with different manure and fertilizer schedules for 29 years had no marked change on electrical conductivity and pH of the soil. Greeval et al. (1999) observed that application of both P and K marginally increased the soil pH both in surface and sub-surface layers than their respective controls. However, after 18 years of crop rotation there was drastic increase in electrical conductivity of soil from 0.56 to 1.29 d S $m^{-1}$.

Kadam (1999) reported that the soils were low to very low in soluble salt concentration with electrical conductivity ranging between 0.07 to 0.53 d S $m^{-1}$ and the soils developed at upper and middle sector in general have low electrical conductivity. Sharma et al. (2007) noticed that after continuous cropping for 31 years soil pH and electrical conductivity increased slightly.

## Assessment of biological parameters in sorghum-wheat cropping system under long term fertilization

Linch and Panting (1980) reported that the soil biomass increased during the growth of wheat crop and then decreased to an approximately constant amount. Ritz and Robinson (1988) reported that biomass carbon showed a sharp increase up to approximately 50 days after sowing and decline thereafter, showing no relation with crop growth.

According to Patra et al. (1990) cultivation of wheat crop showed lower biomass C (689 kg $ha^{-1}$) and biomass N (150 kg $ha^{-1}$) in soil as compared to grass land soils (1121 kg per ha) and (255 kg $ha^{-1}$) respectively. Jain et al. (2003) after 25 years of long term fertilizer experiment at livestock Farm JNKVV, Jabalpur it was found that chemical fertilizers did not have any negative impact on *Nitrosomonas*, *Nitrobacter* and *Azotobacter* population although they were enhanced as compared to control. Recommended dose of NPK without S was less effective for *Nitrosomonas* and *Azotobacter*. Furthermore FYM application was much superior in maintaining the soil biological health with ultimately reflected on ammonical and nitrate N.

Singh (2003) observed that high status of SMBN and SMBP in the NPK + FYM treated plots followed by NPK and control in Vertisols due to improvement of water soluble fraction in these treatments under continuous cropping of sorghum-wheat sequence while continuous application of fertilizer N and P either alone or in combination did not improve active pools of nutrient. Selvi et al. (2004) revealed that amongst the microbes bacterial population was highest as compared to fungi and actinomycetes in soil after cropping sequence of finger millet-maize-cowpea. The application of FYM @ 10 t $ha^{-1}$ to finger millet annually along with 100% NPK recorded the highest bacterial counts at the end of rotation followed by 150% NPK and also observed the mean microbial biomass C and N ranged from 238 to 246 mg $kg^{-1}$ and 27 to 56 mg $kg^{-1}$ respectively and a gradual increase in biomass C and N content of the soil for graded levels of NPK from 50% to 150%. Further it was also observed that 25 % build up in biomass C in optimal NPK dose as compared to control.

Considering the importance of soil fertility to improve productivity the study on long term fertilization occupies major role in integrated nutrient management. The agricultural scenario of India was completely changed due to modern intensive agriculture with high doses of fertilizers, insecticides and high yielding fertilizer responsive varieties of crops. Long term fertilizer experiments can be used for monitoring the changes in soil fertility and crop productivity.

## Conflict of interest statement

Authors declare that they have no conflict of interest.

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