



## Rice (*Oryza sativa*)-wheat (*Triticum aestivum*) yield, nutrient content and their uptake and soil parameters as influenced by summer green manures and fertilizer management in rice-wheat cropping system

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Rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) are most important cereal food crops which contribute about 45% of digestible energy and about 30% total protein in human diets and have a substantial contribution towards feeding of livestock (Evans 1993). At present about 10 m ha area is under rice-wheat production system (RWPS) in Indo-Gangetic plains. Since the introduction of RWPS in Indo-Gangetic plains, the Punjab, Uttar Pradesh and Haryana have been contributing the major share of rice and wheat to the foodgrain pool of the country (Chhibba 2010). However, this system of monoculture in quest of increasing rice-wheat food has degraded soil and water resources of the country which needs to be restored immediately for sustaining this production system. The imbalance supply of chemical fertilizers without or less addition of organic sources to soil has led the depletion of soil nutrient reserve as well as poor nutrient uptake by crop resulting into deficiency of many micronutrients in human diets. Micronutrients are not only essential for better productivity of crop but, also important for sustaining human and animal health (Rattan *et al.* 2009). Soil health sustainability as well as quality cereal foodgrain production is of major concern in high cropping intensity areas. During last two decades production and productivity of rice-wheat crops have become static due to declining soil health and high intensity cropping system coupled with imbalanced supply of chemical fertilizers resulting into deficiency of certain plant nutrients in soil (Srivastava *et al.* 2009). Decreasing organic carbon level in soil needs to

be restored immediately because being a food stock for microbial population it indirectly medicates various chemical and biological reactions and also creates a favourable physical environment in soil for maintaining organic fertility. Therefore, regular supply of green manures becomes essential.

To improve the productive and better uptake of nutrients by grain, balanced supply of plant nutrients through inclusion of summer green manuring in rice-wheat sequence seems more fruitful rather than options available. Further, introduction of summer green manuring having exact match with time frame available between harvest of wheat crop and transplanting of rice is supposed to be third alternative for improving soil health of rice-wheat cropping system (RWCS) in Indo-Gangetic plains under assured irrigated conditions. Keeping these facts in mind, the three summer green manure crops, viz. greengram (*Vigna radiata* L.), sunnhemp (*Crotalaria juncea* L.) and dhaincha (*Sesbania aculeata* Poir) were grown to study their effect on grain yield, nutrient content in plant and their uptake by grain during 2003 to 2006 and pool data of the results have discussed and summarized here.

Field experiments were conducted at research farm of Banaras Hindu University, Varanasi for two years during 2003-2006. Soil was sandy loam in texture (54.4%), sand, 26.28% silt and 19.32% clay), low in organic carbon (0.40%), available N (211.7 kg/ha) and available sulphur (21.9 kg/ha). The available Fe, Cu, Mn and Zn in experimental soil were 22.0, 3.6, 17.6 and 3.2 mg/kg respectively. Cation exchange capacity (CEC), electrical conductivity (EC) and pH of soil were 17.3 [cmol (p<sup>+</sup>)/kg] 0.22 dS/m and 7.8 respectively. Twenty treatment combinations having three legume crops, viz. greengram, sunnhemp, dhaincha and one fallow with N levels (0, 30, 60, 90 and 120 kg/ha) with three replications in split plot design were planned and executed. Summer greengram in mid of April and sunnhemp and dhaincha in

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mid of May were sown in field. The green manure crops were fertilized with 40 kg P<sub>2</sub>O<sub>5</sub> and incorporated into field at suitable time. Rice crop was transplanted at 20 cm × 10 cm spacing and basal application of 60 kg P<sub>2</sub>O<sub>5</sub> and 60 kg K<sub>2</sub>O/ha through single super phosphate and potassium chloride was done. Further the rice crop received N doses as per treatments through urea at the rate of 50% at transplanting 25% at tillering and 25% at panicle initiation stage. The soil samples were taken before transplanting and after harvest of rice crop. Standard methods and procedures were followed for analysis of soil and plant materials as described by Black (1965), Jackson (1973) and Lindsay and Norvell (1978).

#### *Nutrient potential of summer green manures*

The amount of green matter added to soil through greengram, sunnhemp and *dhaincha* was 17.30, 32.65 and 35.55 tonnes/ha respectively (Table 1). Dry matter addition capacity of these summer green manure (SGM) crops was found to be 3.94, 5.87 and 5.71 tonnes/ha respectively. The N, P and K gain to soil through these SGM crop was 79.6, 126.8 and 120.5 kg/ha respectively. The C: N ratio of these SGM crops was also found to be ideal for rapid decomposition in soil.

#### *Rice-wheat grain yield*

Data pertaining to rice and wheat grain yield (Table 5) revealed that maximum yield was harvested from the plot receiving green manuring along with recommended dose of N (i.e. 120 kg/ha) followed by 90, 60 and 30 kg N/ha during both the years of cropping. Sunnhemp incubated treatment produced highest yield of rice followed by *dhaincha* and greengram during the course of study, while in case of wheat, *dhaincha* treated plot registered highest grain yield followed by sunnhemp and greengram respectively. Narrow C: N ratio of sunnhemp (16.1) as compared to *dhaincha* (16.4) leading to quick mineralization might have released nutrients at faster rate resulting into higher yield of rice in sunnhemp incubated plot than *dhaincha* incubated field. Further, higher number of tillers and test weight resulted in higher grain yield of rice and wheat due to significant improvement in wet soil NH<sub>4</sub>-N and oxidized soil NO<sub>3</sub>-N at the different growth stages of crop. Goswami *et al.* (1988) while working on effects of green manuring also observed a significant favourable effect on crop.

#### *Macronutrient content in rice-wheat and their uptake by grain*

The data pertaining to NPK content in rice-wheat plant and their uptake by grain is given in Table 3. Data reveals that NPK contents at tillering stage were significantly higher with incorporation of green manuring in all treatments than that under fallow treatment in both the years of experimentation. The reason may be that quick release of NH<sub>4</sub><sup>+</sup>-N due to microbial decomposition of organic matter

resulting into good response of rice to added organic matter. Increased supply of N further enhanced the concentration of NPK in plant at tillering stage and their uptake in grain at maturity. The mean concentration of these nutrients in plant at different stages and their uptake in grain were highest with highest levels of N applied and lowest in control. Maximum NPK content was observed at early stage of crop growth and then it went on decreasing gradually with the advancement of crop growth. These findings are in line of those reported by Tiwari *et al.* (1980) who reported that import and export of mineral nutrients occur simultaneously during the life of plant organs such as leaves. As a rule ageing (senescence) is associated with higher rate of export of mineral nutrients than rate of organ such as leaf. Thus decrease in net content is important during the autogenesis of a plant at following stage of seed germination period of insufficient supply of the root during vegetative growth, reproductive growth and in perennial the period before leaf drop (Marschner 1992). The increase in uptake of nutrients may be due to better availability of these nutrients through additional supply and because of prolific root system development by balance nutrients application, resulting into better absorption of water and nutrients. Integrated use of inorganic and organics through green manuring was beneficial in enhancing the uptake of NPK by rice and wheat grain. Moreover organic matter after decomposition releases both macro and micro nutrients which become available to the plant and thus increase the uptake of NPK. Sharma *et al.* (2001) also had the opinion that incorporation of green manures to soil encourages proliferation of roots resulting in to more absorption of water and nutrients from more area in depth of soil. The uptake NPK by grain of rice and wheat were highest due to incorporation of green manures along with 120 kg N/ha followed by the application of 90 kg N/ha as urea. These findings are similar to the result of Goswami *et al.* (1988), Mahapatra *et al.* (1997) and Mahapatra and Jee (1993). Data further reveals that in case of rice higher uptake of NPK was in sunnhemp incorporated plot along with 120 kg N/ha followed by 90 kg N/ha, while in the case of wheat grain uptake recorded in *dhaincha* green manures incorporated plots along with similar dose of rice crop.

*Micronutrients content and their uptake:* The cycling of micronutrients through the soil plant animal system is a generalized dynamics. The organic chelates, soil colloids, soil organic matter and soil minerals all contribute to micronutrients in soil solutions and in turn their availability to growing plants. Organic matter is also an important secondary source of some of the trace elements. Soil pH is most important factor governing micronutrients availability to plants in soil. The decomposition of green manures in submerged condition release organic acid and green manures sap are acidic in nature which reduce soil pH during decomposition and enhance availability of micronutrients to

growing crops. The green manures crop are comparatively deep rooted and have more mining capacity to nutrients specially of micronutrients which after decomposition leave micronutrients in plough layer depth. The finding of the present study indicate that the copper, zinc, iron and manganese content at different stages of crop and grain increased due to green manuring as the plot accumulated higher amount of micronutrients as compared to fallow plots. The copper and zinc content in rice were higher in sunnhemp incorporated plot followed by *dhaincha* fed plots while iron and manganese contents were maximum in *dhaincha* grown field followed by sunnhemp treated plot. In case of wheat crop, copper, zinc, iron and manganese were found to be higher in *dhaincha* grown field followed by sunnhemp manured plots with N applied through urea. Green manures resulted into marked improvement in nutrients concentration in rice and wheat crop especially of NPK, Fe, Mn, and Zn over the fallow plots. The findings of Swarup (1991) also supported these results. The green manures after decomposition release both macro and micro nutrients which become available to plots and thus increased the content and their uptake by crops. These finding are also supported by Sharma *et al.* (2001). The production of certain organic compounds during decomposition might have been related to chelates formation with metal micronutrients and consequently higher uptake of these chelated forms by plants. Organic matter itself also acts as an important secondary source of micronutrients. Micronutrients made complex with organic section and resulted in more uptake of them by crops. Over all the results of study revealed that inclusion of summer green manures in rice-wheat cropping sequence has been beneficial in improving soil properties, nutrient uptake by grain and crop yield.

#### *Soil parameters*

**Bulk density (BD):** Bulk density is most likely property to be affected by level of organic matter in soil because, added material has lower density than soil matrix therefore, the relationship between improved aggregate conditions and a reduction in bulk density is well established. Data given in Table 3 reveal that BD of soil got decreased significantly in sunnhemp supplied plot followed by *dhaincha* and greengram after harvest of rice, but in case of wheat significant reduction in BD occurred in *dhaincha* fed plot followed by sunnhemp and greengram either alone or in combination with fertilizers after harvest. The variation in C: N ratio of sunnhemp (16.1) and *dhaincha* (16.4) might have affected the rate of decomposition of green manures in soil. Sunnhemp having narrow C:N ratio (16.1) might have decomposed faster thereby decreasing the BD of soil, whereas wider C:N ratio of *dhaincha* (16.4) than sunnhemp consumed more time and showed the reduction in BD of soil after harvest of wheat. During decomposition process of organic matter various polysaccharides, polyuronides and

humus are produced which may be responsible for binding the soil particles resulting in more stable aggregates and causing reduction in bulk density. Significant reduction in bulk density is closely related with increased cumulative infiltration. Further, reduction in bulk density also occurs due to relatively higher organic matter content in soil which would have improved porosity of such soil. De Haan (1977) had reported that green manures added to sandy soil decreased bulk density. Jamison (1960) emphasized it as indirect improvement in BD though the improvement in aggregate distribution and stability. These observations are also in agreement with the findings of Thakur *et al.* (1995) and Sharma *et al.* (2001).

**Changes in pH and EC:** The properties of soil most likely to be affected by organic matter in the form of green manures are pH, redox potential, and electrical conductivity, partial pressure of CO<sub>2</sub> and surface properties of soils. Nutrient transformations brought about by green manuring are direct consequences of changes in these properties. After harvest of rice and wheat crop addition of green manure along with fertilizer N reduced pH and increased electrical conductivity (EC) of soil as compared to control plot. Decrease in pH was greater in treatment receiving *dhaincha* as summer green manure followed by sunnhemp and greengram respectively. Green manuring affects soil pH in two ways by producing organic acids and CO, during decomposition which can furnish protons to soil inducing a decrease in pH. Green manure crops produce sap acid during decomposition consequently reducing soil pH. These findings are in line with that of Swarup (1991) and Bellakki and Badanur (1997).

Generally it is noticed that little or no change in EC occurs by applying organic manures because even with fertilizers (which are soluble salts) the increase in EC has been short lived. Under waterlogged conditions EC of soil solution increases with time, reaches a peak and then decrease. Addition of green manure would accelerate the decrease in EC and accumulation of CO<sub>2</sub> thereby, release of large amount of ions (Fe<sup>+2</sup>, Mn<sup>+2</sup>, CO<sub>3</sub><sup>-</sup> etc.) in to soil solution and increase in EC. Data pertaining to EC showed that EC of the soil was significantly higher in green manured plus fertilizer supplied plots. The similar results have also been reported by Dekamedhi and Datta (1995). CO<sub>2</sub> evolution study conducted at field capacity up to one month of incubation at 30°C showed that summer green manure treated soil had higher respiration rates than that of fertilizer supplied indicating higher carbon status in green manured soil after harvest of crop. Bellakki and Badanur (1997) have also reported that organic carbon content of surface and subsurface soil increased significantly with recommended dose of fertilizer application. The increase in organic carbon could be attributed to the addition of organic matter through green manures. These findings are in the line of results reported by Bhandari *et al.* (1992).

### Changes in organic carbon and CEC of soil

Organic carbon and cation exchange capacity status of soil after harvest of rice and wheat (Table 3) shows that summer green manuring along with fertilizer N through urea increased organic carbon and cation exchange capacity of soil as compared to control plot. Generally it is accepted that green manures maintain or increase organic matter or increase soil N levels but not both simultaneously. In present study addition of summer green manure along with fertilizer N increased organic carbon significantly over control. Highest addition occurred in sunnhemp treated plot followed by *dhaincha* and greengram. The maintenance or accumulation of organic matter in soil is dependent on a number of factors, e.g. chemical natures of added material, soil and climatic factors affecting microbial and cultural practices. Generally CEC of soil is governed by kind and nature of organic colloids, humus, iron and aluminum oxides. CEC of soil increased due to improvement in organic matter content of soil. Addition of organics along with fertilizer increased the CEC of soil over control followed by application of full recommended dose of fertilizer. These findings are in agreement of the results reported by Sharma *et al.* (2001).

### SUMMARY

Three leguminous crops, viz. greengram (*Vigna radiata* L.), sunnhemp (*Crotalaria juncea* L.) and *dhaincha* (*Sesbania aculeata* Poir) were grown in summer season to study the response of rice-wheat and soil in relation to grain yield, nutrient content in plant and their uptake by grain. The study explained that fresh weight of organic matter added by sunnhemp, *dhaincha* and greengram was 32.65, 35.55 and 17.30 tonnes/ha respectively. N supplying capacity of sunnhemp, *dhaincha* and greengram was recorded to be 126.8, 120.5 and 79.6 kg/ha respectively, that of P supplying capacity 27.0, 31.4 and 17.3 kg/ha and that of K 130.3, 137.6 and 98.5 kg/ha respectively. Sunnhemp and *dhaincha* supplied treatments along with 120 kg nitrogen registered maximum yields of rice and wheat. Further, summer green manuring along with inorganic fertilizer decreased bulk density and pH of soil, whereas electrical conductivity, organic carbon and cation exchange capacity of soil increased. Nutrient contents in rice-wheat plants at different stages and their translocation to rice and wheat grain also increased. Conclusively it emerged that summer green manuring practice has appeared as best third alternative for sustaining rice-wheat yield and soil health in Indo-Gangetic plains therefore, seasonal summer fallow fields may be used for growing of summer green manures and higher yields of rice and wheat could be obtained.

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