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# Effect of phosphorus and farmyard manure applied to sunnhemp (*Crotalaria juncea*) on yield and nutrient uptake of sunnhemp– wheat (*Triticum aestivum* ) cropping system and fertility status in a Typic Ustocrept of Uttar Pradesh

D N MAITRA[1], S K SARKAR[2], S SAHA[3], M K TRIPATHI[4], B MAJUMDAR [5] and A R SAHA[6]

*Central Research Institute for Jute and Allied Fibres, Barrackpore, Kolkata, West Bengal 700 120*

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ABSTRACT

A field experiment with sunnhemp (*Crotalaria juncea* L.) –wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system was conducted during 2004 and 2005 to study the effect of phosphorus and farmyard manure levels on yield and nutrient uptake of sunnhemp and their residual effect on wheat and changes in soil fertility status. Application of farmyard manure @ 5 tonnes/ha recorded an increase of 13.9% in fibre yield over the no farmyard manure. Fertilizer phosphorus significantly increased the fibre yield of sunnhemp by 14.69% over the no phosphorus at 40 kg $P_2O_5$ /ha. The highest fibre yield (0.90 tonne/ha) was recorded with combined application of 60 kg $P_2O_5$ and 7.5 tonnes farmyard manure/ ha which was 45.2% higher than the yield of without phosphorus and farmyard manure. The total nitrogen, phosphorus and potassium uptake by sunnhemp increased significantly with applied phosphorus up to the maximum level of 60 kg $P_2O_5$/ha but the favourable effect with farmyard manure was recorded up to 5 tonnes/ha only. The increase in nitrogen, phosphorus and potassium uptake with 60 kg $P_2O_5$/ha were 20.5, 44.0 and 54.9% respectively over no phosphorus. Grain and straw yield of wheat increased significantly with farmyard manure at 5 and 7.5 tonnes/ha applied in sunnhemp over no farmyard manure although the yield recorded with 5 and 7.5 tonnes farmyard manure/ ha were at par. The increase in grain and straw yield under 5 tonnes farmyard manure/ha was 6.60 and 14.05% respectively. Combined dose of 60 kg $P_2O_5$ with 7.5 tonnes farmyard manure/ha applied in sunnhemp recorded highest grain yield of wheat (4.55 tonnes/ha) which was 21.3% higher than that of without phosphorus and farmyard manure. The nitrogen, phosphorus and potassium uptake by wheat crop increased significantly due to the residual effect of farmyard manure and phosphorus applied in sunnhemp crop. Application of phosphorus and farmyard manure had significantly improved the organic carbon and available nitrogen, phosphorus and potassium status in post-harvest soil after 2 years of cropping.

**Key words:** Farmyard manure, Fertilizer phosphorus, Sunnhemp, Wheat, Alkaline soil

Sunnhemp (*Crotalaria juncea* L.), a leguminous green manure crop is grown commercially as a fibre crop in various parts of India including Uttar Pradesh. India is the largest producer of sunnhemp fibre in the world, followed by Bangladesh and Brazil. Sunnhemp crop rotation is very common in Pratapgarh distict of Uttar Pradesh. The use of organics either in the form of manure, green manure or bio-fertilizer is getting momentum now a days for sustainable crop production. Integration of organic and inorganic sources of nutrients and their use is, therefore, considered as the ultimate option for management of soil fertility. Response of applied nitrogen has not been very much pronounced on the growth of plants and fibre yield while application of phosphorus resulted in production of more fibre coupled with more bacterial activites in fixation of nitrogen (Tripathi *et al.* 1998). Phosphorus availability is a limiting factor for sunnhemp–wheat cropping system in the Inceptisol (*Typic Ustocrept*). Farmyard manure when applied in combination with phosphorus, it reduces the fixation of phosphorus and consequently increased the availability of applied inorganic phosphorus (Subba Rao *et al.* 1998, Venkatesh *et al.* 2002). Moreover the soils of the study site in Pratapgarh district are very poor in organic carbon (2.8 g/kg), the retention of various applied nutrients from inorganic sources is very low and thus the fertilizer use efficiency also becomes very low. The present experiment was, therefore, conducted to integrate the effect of phosphorus and farmyard manure levels on yield and nutrient uptake by sunnhemp–wheat cropping system and changes in soil fertility status in slightly alkaline soils of Uttar Pradesh.

[1] Scientist (Selection Grade), [3] Principal Scientist, [5,6] Senior Scientist, Division of Crop Production; [2] Senior Scientist, [4] Scientist, Sunnhemp Research Station, Pratapgarh, UP 230 001

## MATERIALS AND METHODS

The field experiment was conducted to assess the effect of phosphorus and farmyard manure on sunnhemp and their

residual effect on succeeding wheat for consecutive two years during *kharif* and *rabi* seasons of 2004 and 2005 at Sunnhemp Research Station, Pratapgarh, Uttar Pradesh (between 25°34′ and 26°11′ latitudes and between 81°19′ and 82°27′ longitudes) on sandy loam soil with *p*H 7.8, organic carbon 2.8 g/kg, bulk density 1.44 g/cc, $CaCO_3$ 7 to 10 g/kg and available nitrogen, phosphorus and potassium 224, 12 and 185 kg/ha respectively. There were 16 treatment combinations consisting of 4 levels of phosphorus (0, 20, 40 and 60 kg $P_2O_5$ /ha) and 4 levels of farmyard manure (FYM) (0, 2.5, 5.0 and 7.5 tonnes/ha) replicated thrice in randomized block design. The treatments were as follows : $T_1$, $P_0FYM_0$; $T_2$, $P_0FYM_{2.5}$; $T_3$, $P_0FYM_5$; $T_4$, $P_0FYM_{7.5}$; $T_5$, $P_{20}FYM_0$; $T_6$, $P_{20}FYM_{2.5}$; $T_7$, $P_{20}FYM_5$; $T_8$, $P_{20}FYM_{7.5}$; $T_9$, $P_{40}FYM_0$, $T_{10}$, $P_{40}FYM_{2.5}$; $T_{11}$, $P_{40}FYM_5$; $T_{12}$, $P_{40}FYM_{7.5}$; $T_{13}$, $P_{60}FYM_0$, $T_{14}$, $P_{60}FYM_{2.5}$; $T_{15}$, $P_{60}FYM_5$; and $T_{16}$,$P_{60}FYM_{7.5}$. Farmyard manure and phosphorus were applied in sunnhemp crop but not in wheat crop. Farmyard manure containing 0.70, 0.30 and 0.87%, nitrogen, phosphorus and potassium, respectively, was applied 15 days before sowing. 'K-12' yellow sunnhemp was sown during third week of April in *kharif* season and 'UP 262' wheat was sown during third week of November during *rabi* season in both the years. Seed rate used for sunnhemp and wheat was 40 and 125 kg/ha respectively. Sunnhemp and wheat were sown at 25 and 20 cm row spacing respectively. Nitrogen, phosphorus and potassium were applied respectively through urea, single super-phosphate and muriate of potash. A common dose of 20 kg nitrogen and 40 kg $K_2O$/ha in sunnhemp and 120 kg nitrogen and 60 kg $K_2O$/ha in wheat was applied. The full dose of potassium was applied as basal in both the crops while nitrogen was applied in 2 splits- half as basal and another half at 30 days crop age. Rainfall during the crop periods of *kharif* and *rabi* season was 378.5, 57.5, 242 and 11 mm during 2004 and 2005 respectively. The maximum and minimum temperature were 38–45°C and 19.2–24°C (*kharif* 2004), 25-37.4°C and 6.5-16°C (*rabi* 2004), 41–46°C and 20–24°C (*kharif* 2005), 29-40°C and 4-14°C (*rabi* 2005). Analysis of plant nitrogen, phosphorus and potassium was done following standard procedures. The yield and nutrient uptake data are presented as pooled mean of 2 years. The post-harvest soil samples after 2 years were analyzed for organic carbon, available nitrogen, available phosphorus and available potassium.

## RESULTS AND DISCUSSION

*Sunnhemp fibre yield and nutrient uptake*

Application of phosphorus and farmyard manure significantly influenced the fibre yield of sunnhemp and their nutrient uptake (Table 1) although the interaction between phosphorus and farmyard manure was non-significant for yield, nitrogen and phosphorus uptake. The effect of farmyard manure on fibre yield of sunnhemp was significant up to 5 tonnes/ha and further increase of 2.5 tonnes/ha had no significant effect. Application of farmyard manure @ 5 tonnes/ha recorded an increase of 13.9% in fibre yield over no farmyard manure. Effect of farmyard manure on increasing yield of pearl millet [*Pennisetum glacum* (L.) R.Br.emend. Stuntz] and blackgram (*Vigna mungo* L. Hepper) was also reported by Jakhar *et al.* (2006) and Shrivastava *et al.* (2003) respectively. The increase in fibre yield with farmyard manure might be because of additional supply of plant nutrients as well as improvement in physical properties of the soil. Fertilizer phosphorus significantly increased the fibre yield of sunnhemp up to 40 kg $P_2O_5$ /ha and further increase in phosphorus level up to 60 kg $P_2O_5$ /ha remained at par. The extent of increase in fibre yield of sunnhemp by application of 40 kg $P_2O_5$/ha was 14.69% over no phosphorus. The experimental soil was medium in available phosphorus status (kg $P_2O_5$/ha), so the response of sunnhemp crop to the applied phosphorus was in tune with phosphorus status. The favourable effect of phosphorus with farmyard manure may be due to the fact that that organic anions and hydroxyl acids liberated

Table 1 Integrated effect of phospuorus and farmyard manure on fibre yield and nutrient uptake by sunnhemp (pooled data of 2 years)

| FYM (tonnes /ha) | Fertilizer phosphorus (kg $P_2O_5$ /ha) 0 | 20 | 40 | 60 | Mean |
|---|---|---|---|---|---|
| | *Fibre yield (tonnes/ha)* | | | | |
| 0 | 0.62 | 0.70 | 0.75 | 0.80 | 0.72 |
| 2.5 | 0.70 | 0.76 | 0.80 | 0.83 | 0.77 |
| 5.0 | 0.75 | 0.79 | 0.86 | 0.88 | 0.82 |
| 7.5 | 0.79 | 0.82 | 0.88 | 0.90 | 0.85 |
| Mean | 0.72 | 0.77 | 0.82 | 0.85 | |
| CD (*P* =0.05) | P = FYM =0.05, P × FYM = NS | | | | |
| | *N uptake (kg /ha)* | | | | |
| 0 | 170.20 | 190.00 | 210.20 | 231.90 | 200.60 |
| 2.5 | 199.10 | 203.70 | 220.85 | 222.00 | 211.40 |
| 5.0 | 204.80 | 216.00 | 223.30 | 244.70 | 222.20 |
| 7.5 | 208.65 | 217.90 | 225.00 | 245.00 | 224.10 |
| Mean | 195.70 | 206.90 | 219.80 | 235.90 | |
| CD (*P* =0.05) | P = FYM =10.63, P × FYM = NS | | | | |
| | *P uptake (kg /ha)* | | | | |
| 0 | 19.80 | 25.70 | 27.55 | 29.20 | 25.55 |
| 2.5 | 22.90 | 27.20 | 29.00 | 33.20 | 28.10 |
| 5.0 | 24.60 | 29.50 | 31.00 | 36.00 | 30.30 |
| 7.5 | 26.40 | 30.00 | 33.50 | 36.50 | 31.6 |
| Mean | 23.40 | 28.10 | 30.30 | 33.70 | |
| CD (*P* =0.05) | P = FYM =2.15, P × FYM = NS | | | | |
| | *K uptake (kg /ha)* | | | | |
| 0 | 71.10 | 84.60 | 107.80 | 142.00 | 101.30 |
| 2.5 | 91.50 | 113.60 | 132.80 | 144.50 | 120.60 |
| 5.0 | 108.70 | 133.60 | 145.70 | 149.10 | 134.30 |
| 7.5 | 110.00 | 134.00 | 153.20 | 155.00 | 138.00 |
| Mean | 95.30 | 116.45 | 134.90 | | |
| CD (*P* =0.05) | P = FYM =5.57, P × FYM =11.14 | | | | |

during organic matter decay have immobilized calcium, magnesium etc. through complextion or chelation and thereby prevented phosphate ions from reacting with calcium and magnesium. This was in agreement with the findings of Subba Rao *et al.* (1998) and Majumdar *et al.* (2002). The interaction effects of phosphorus and farmyard manure were non-significant. The highest fibre yield (0.90 tonne/ha) was recorded with combined application of 60 kg $P_2O_5$ and 7.5 tonnes farmyard manure/ha which was 45.2% higher than the yield without phosphorus and farmyard manure. The total nitrogen, phosphorus and potassium uptake by sunnhemp increased significantly with applied phosphorus up to the maximum level of 60 kg $P_2O_5$/ha but the favourable effect with farmyard manure was recorded up to 5 tonnes/ha only and thereafter increase in uptake was non-significant with increment in farmyard manure dose to 7.5 tonnes/ha (Table 1). The increase in nitrogen, phosphorus and potassium uptake with 60 kg $P_2O_5$/ha were 20.5, 44.0 and 54.9% respectively over no phosphorus . The increase in nitrogen and potassium uptake with applied phosphorus may be attributed to the better root growth which led to more absorption of nitrogen and potassium from reserve pool in the soil. Application of farmyard manure had significantly influenced the nitrogen, phosphorus and potassium uptake by sunnhemp. The increase in nitrogen, phosphorus and potassium uptake by application of 5 tonnes farmyard manure/ha was 10.77, 18.59 and 32.58% respectively over no farmyard manure. The beneficial effect of farmyard manure on uptake of nutrients could be due to the additional supply of these nutrients through farmyard manure and release of these nutrients from soil due to solubilizing effect on reserve/fixed pool of nutrients (Venkatesh *et al.* 2002). The interaction effects between phosphorus and farmyard manure was non- significant for nitrogen and phosphorus uptake but the same was significant for potassium uptake by sunnhemp. The maximum nitrogen, phosphorus and potassium uptake by sunnhemp was recorded with a combination of 60 kg $P_2O_5$ and 7.5 tonnes farmyard manure/ ha.

*Wheat yield and nutrient uptake*

The wheat crop was grown during *rabi* season to find out the residual effect of phosphorus and farmyard manure applied to previous crop sunnhemp. The data in Table 2 indicates that the grain and straw yield of wheat increased significantly with farmyard manure at 5 and 7.5 tonnes/ha applied in sunnhemp over no farmyard manure although the yield recorded with 5 tonnes and 7.5 tonnes farmyard manure/ ha were at par. The increase in grain and straw yield under 5 tonnes farmyard manure/ha was 6.60 and 14.05% respectively. The effect of phosphorus on grain and straw yield of wheat was non-significant. This indicates that phosphorus applied in preceding crop sunnhemp was not adequate to produce optimum yield of wheat. The interaction effect of phosphorus and farmyard manure was non-significant for grain and straw

Table 2 Residual effect of phosphorus and farmyard manure on yield and nutrient uptake by wheat (pooled data of 2 years)

| FYM (tonnes/ha) | Fertilizer P (kg $P_2O_5$ /ha) 0 | 20 | 40 | 60 | Mean |
|---|---|---|---|---|---|
| | *Grain yield (tonnes/ha)* | | | | |
| 0 | 3.75 | 3.89 | 4.02 | 4.10 | 3.94 |
| 2.5 | 3.93 | 4.12 | 4.24 | 4.30 | 4.15 |
| 5.0 | 3.99 | 4.19 | 4.27 | 4.37 | 4.20 |
| 7.5 | 4.21 | 4.42 | 4.52 | 4.55 | 4.42 |
| Mean | 3.97 | 4.16 | 4.26 | 4.33 | |
| CD (*P* =0.05) | P = NS, FYM =0.23, P × FYM = NS | | | | |
| | *Straw yield (tonnes /ha)* | | | | |
| 0 | 4.57 | 4.76 | 4.95 | 5.08 | 4.84 |
| 2.5 | 5.03 | 5.11 | 5.42 | 5.55 | 5.28 |
| 5.0 | 5.27 | 5.51 | 5.58 | 5.73 | 5.52 |
| 7.5 | 5.32 | 5.94 | 6.13 | 6.13 | 5.88 |
| Mean | 5.05 | 5.33 | 5.52 | 5.62 | |
| CD (*P* =0.05) | P =NS, FYM =0.369, P × FYM = NS | | | | |
| | *N uptake (kg /ha)* | | | | |
| 0 | 87.20 | 88.50 | 92.80 | 95.70 | 91.00 |
| 2.5 | 93.70 | 100.65 | 105.70 | 107.00 | 101.80 |
| 5.0 | 103.10 | 108.60 | 113.70 | 114.65 | 110.00 |
| 7.5 | 106.60 | 114.60 | 119.90 | 119.70 | 115.20 |
| Mean | 97.65 | 103.10 | 108.00 | 109.30 | |
| CD (*P* =0.05) | P = FYM =6.85, P × FYM = NS | | | | |
| | *P uptake (kg /ha)* | | | | |
| 0 | 13.10 | 14.00 | 16.00 | 15.80 | 14.70 |
| 2.5 | 15.60 | 15.90 | 17.20 | 17.40 | 16.50 |
| 5.0 | 16.60 | 17.00 | 18.80 | 19.40 | 17.90 |
| 7.5 | 17.80 | 18.70 | 21.10 | 22.40 | 20.00 |
| Mean | 15.80 | 16.40 | 18.30 | 18.70 | |
| CD (*P* =0.05) | P = FYM =1.02, P × FYM = NS | | | | |
| | *K uptake (kg /ha)* | | | | |
| 0 | 84.10 | 88.80 | 95.50 | 95.40 | 90.90 |
| 2.5 | 95.65 | 98.30 | 106.40 | 107.50 | 101.25 |
| 5.0 | 106.90 | 106.50 | 112.30 | 114.70 | 110.10 |
| 7.5 | 109.50 | 120.60 | 125.80 | 127.80 | 120.90 |
| Mean | 99.00 | 103.50 | 110.00 | 111.3 | |
| CD (*P* =0.05) | P = FYM =8.20, P × FYM = NS | | | | |

yield. Highest grain yield (4.55 tonnes/ha) was recorded with 60 kg $P_2O_5$ integrated with 7.5 tonnes farmyard manure/ ha, followed by 40 kg $P_2O_5$ integrated with 7.5 tonnes farmyard manure/ha. The yield obtained with the former treatment was 21.33% higher than that of without phosphorus and farmyard manure. Similar significant residual effect of farmyard manure and phosphorus applied in previous crop maize was noticed on the yield of subsequent crop mustard by Mahala *et al.* (2006).

The nitrogen, phosphorus and potassium uptake by wheat crop increased significantly with farmyard manure and

phosphorus application in sunnhemp crop although the increase with farmyard manure was more prominent than applied phosphorus. In case of farmyard manure, the phosphorus and potassium uptake by wheat increased significantly up to the maximum level of 7.5 tonnes/ha application while the nitrogen uptake increased at 5 tonnes/ha application only. Nitrogen, phosphorus and potassium uptake by wheat increased significantly up to 7.5 tonnes/ha farmyard manure application in sunnhemp. However, there was no significant difference in nitrogen uptake by wheat between 5 and 7.5 tonnes/ha farmyard manure application. The extent of increase in nitrogen, phosphorus and potassium uptake by wheat was 26.59, 36.05 and 33% respectively over no farmyard manure. The nitrogen, phosphorus and potassium uptake by wheat with applied phosphorus in sunnhemp significantly increased at 40 and 60 kg $P_2O_5$/ha over no phosphorus although there was no significant difference between 40 and 60 kg $P_2O_5$ application. The increase in nitrogen, phosphorus and potassium uptake was 10.60, 15.82 and 11.11% respectively at 40 kg $P_2O_5$/ha over no phosphorus added to preceding crop sunnhemp. This was in agreement with the results of Singh and Singh (2006) with urdbean-wheat cropping system. The phosphorus × farmyard manure interaction was non-significant for nutrient uptake by wheat crop and the maximum uptake of nitrogen, phosphorus and potassium were recorded with a combination of 60 kg $P_2O_5$ and 7.5 tonnes farmyard manure/ha application in sunnhemp.

*Soil fertility status*

The organic carbon content increased significantly with the application of farmyard manure and phosphorus (Table 3), which might be due to the addition of organic carbon through farmyard manure, incorporation of biomass through root and leaf fall from the plants in varying degrees and creation of favourable conditions for the growth of soil microorganisms. This was in agreement with the findings of Venkatesh *et al.* (2002). The interaction between phosphorus and farmyard manure was non-significant for organic carbon build up in post-harvest soil. There was significant improvement in available nitrogen with phosphorus and farmyard manure application (Table 2) over control in the soil indicating its substantial build up due to increased biological $N_2$ fixation (Kundu *et al.* 1998). The available nitrogen status follows the trend of organic carbon build up in the soil. Available nitrogen content in post-harvest soil increased by 6.3% with 7.5 tonnes farmyard manure/ha application over no farmyard manure and by 6.9% with 60 kg $P_2O_5$ /ha application over no phosphorus. The interaction between phosphorus and farmyard manure was non-significant although the available nitrogen content increased with the increase in farmyard manure doses at any particular phosphorus dose and vice versa. The maximum available nitrogen (256 kg N/ha) was recorded with 60 kg $P_2O_5$ and 7.5 tonnes farmyard manure/ha which was 15.3% higher over no phosphorus and no farmyard manure.

Table 3 Effect of phosphorus and farmyard manure on organic carbon and available nutrient status in post harvest soil (after 2 years)

| FYM (tonnes/ha) | Fertilizer P (kg $P_2O_5$ /ha) 0 | 20 | 40 | 60 | Mean |
|---|---|---|---|---|---|
| | *Organic carbon content (g kg)* | | | | |
| 0 | 3.0 | 3.2 | 3.5 | 3.7 | 3.3 |
| 2.5 | 3.4 | 3.6 | 3.7 | 3.9 | 3.6 |
| 5.0 | 3.6 | 3.8 | 4.0 | 4.0 | 3.8 |
| 7.5 | 3.9 | 4.0 | 4.2 | 4.3 | 4.1 |
| Mean | 3.5 | 3.7 | 3.8 | 4.0 | |
| CD ($P$ =0.05) | P = NS, FYM = 0.01, P × FYM = NS | | | | |
| | *Available N (kg /ha)* | | | | |
| 0 | 222 | 231 | 237 | 244 | 234 |
| 2.5 | 233 | 238 | 242 | 248 | 240 |
| 5.0 | 238 | 241 | 246 | 251 | 244 |
| 7.5 | 241 | 245 | 251 | 256 | 248 |
| Mean | 234 | 239 | 244 | 250 | |
| CD ($P$ =0.05) | P = FYM = 3, P × FYM = NS | | | | |
| | *Available P (kg /ha)* | | | | |
| 0 | 12.30 | 12.95 | 14.20 | 14.20 | 13.40 |
| 2.5 | 12.75 | 14.00 | 15.50 | 15.40 | 14.40 |
| 5.0 | 13.80 | 15.55 | 17.00 | 18.00 | 16.10 |
| 7.5 | 14.00 | 15.25 | 16.55 | 18.00 | 16.00 |
| Mean | 13.20 | 14.45 | 15.80 | 16.40 | |
| CD ($P$ =0.05) | P = FYM = 0.80, P × FYM = NS | | | | |
| | *Available K (kg /ha)* | | | | |
| 0 | 180 | 185 | 185 | 186 | 184 |
| 2.5 | 183 | 191 | 196 | 204 | 194 |
| 5.0 | 192 | 198 | 202 | 208 | 200 |
| 7.5 | 196 | 202 | 214 | 219 | 208 |
| Mean | 188 | 194 | 199 | 204 | |
| CD ($P$ =0.05) | P = FYM = 5, P × FYM = 10 | | | | |

*Initial soil status* : Organic carbon 2.8 g/kg; nitrogen 224 kg/ha; phosphorus 12 kg/ha and potassium 185 kg/ha

The available phosphorus content of post-harvest soil increased significantly with phosphorus and farmyard manure application. Available phosphorus content in post-harvest soil increased by 24.2% with 60 kg $P_2O_5$/ha application over no phosphorus and 20.2% by 5 tonnes farmyard manure/ha application over no farmyard manure. The efficiency of farmyard manure in increasing phosphorus availability is known to be due to its microbial population as well as the decomposition products of humic substances and reduced phosphate sorption with low bonding energy (Majumdar *et al.* 2002). The interaction between phosphorus and farmyard manure was non-significant for available phosphorus although the same increased up to 60 kg $P_2O_5$/ha with increase in farmyard manure levels up to 5 tonnes/ha non-significantly and the maximum available phosphorus contents (18 kg/ha)

was recorded at 60 kg/ha phosphorus in combination of farmyard manure @ 5 tonnes/ha. There was significant increase in available potassium content in post-harvest soil after 2 years with the applied phosphorus and farmyard manure. The available potassium content increased significantly at each level of applied phosphorus with the increase in farmyard manure levels and vice versa. The interaction between phosphorus and farmyard manure was also significant and the highest value (219 kg $K_2O$/ha) was recorded with 60 kg $P_2O_5$ and 7.5 tonnes farmyard manure/ ha which was 21.7% higher than that of without phosphorus and farmyard manure. Similar increase in organic carbon content and available nitrogen, phosphorus and potassium content in soil with application of farmyard manure and phosphorus by Venkatesh *et al.* (2002) and Shrivastava *et al.* (2003).

Thus from the above study it may be concluded that combined application of 60 kg $P_2O_5$ and 5 tonnes farmyard manure/ha was sufficient for obtaining higher yield from sunnhemp-wheat crop rotation with maintenance of soil fertility in sandy loam soil of Uttar Pradesh.

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