



## Effect of integrated nutrient management on productivity and soil health in pigeonpea (*Cajanus cajan*)-wheat (*Triticum aestivum*) cropping system

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### ABSTRACT

A field experiment was conducted during 2004-07 at the research farm of IARI, New Delhi, to study the nutrient management strategies for pigeonpea [*Cajanus cajan* (L) Millsp]-wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] and its effect on soil health. The sandy loam Typic Haplustept soil of the experimental field was well drained, mildly alkaline and non-saline with medium soil fertility status. In pigeonpea, application of fertilizer NPK at soil-test based recommended rates produced 1.44 t/ha grain yield which was significantly higher as compared with unfertilized control. The highest grain yield (1.79 t/ha) was recorded with NPK+FYM (2.5 tonnes/ha). In wheat crop also, integrated use of NPK and FYM (7.5 tonnes/ha) gave significantly higher grain yield (5.23 t/ha) as compared with general recommended dose of NPK (4.28 t/ha). Conjoint use of fertilizer NPK and FYM, improved soil physical health as revealed by a significant decrease in soil bulk density (BD) and an increase in water holding capacity (WHC) *vis-à-vis* sole fertilizer treatments or unfertilized control during the years of experimentation. Soil BD decreased from 1.50 Mg/m<sup>3</sup> in NPK to 1.40 Mg/m<sup>3</sup> in NPK + FYM + ID plots. Water holding capacity increased from 35.1% in NPK to 39.4% in NPK + FYM plots. Among biological parameters of soil health, microbial biomass C (MBC), microbial biomass N (MBN) and dehydrogenase activity (DHA) were measured, which varied from 178 to 373 mg/kg, 22.8 to 65.8 mg/kg and 43.7 to 61.0 µg TPF/24 h/g of soil, respectively in different treatments. In general, highest values of these parameters were recorded in treatments that received NPK + FYM with or without ID.

**Key words :** Integrated nutrient management, Pigeonpea-wheat sequence, Productivity, Soil health

Intensive cropping systems are exhaustive feeders of plant nutrients, and lead to depletion of soil fertility when a balanced and adequate replenishment of nutrients is continuously ignored. Pigeonpea (extra-short duration)-wheat is a fast-expanding cropping system in the rice-wheat dominated areas of the Upper Gangetic Plains, owing to apparent deficit of irrigation water. The problem is more acute in high productivity areas of Indo-Gangetic Plain region (IGPR) *i.e.*, Trans-Gangetic Plains (TGP, representing Punjab and Haryana) and Upper Gangetic Plains (UGP, representing Delhi and Western U.P.), where intensive cereal-cereal cropping systems are predominantly followed with indiscriminate use of nutrients and irrigation water, and also with excessive tillage using heavy machinery (Yadav *et al.* 1998). Depletion of soil organic carbon (SOC) both in terms of quality and quantity is the major soil health problem emerged due to continuous adoption

of this kind of farming, followed by other constraints like emergence of multi-nutrient deficiencies and deterioration of soil physical properties-especially sub-surface compaction and poor aggregation (Hobbs and Morris 1996). The sustenance of high yields in these otherwise productive areas is becoming increasingly difficult owing to soil-related constraints. Nutrient management strategies for this system need to be developed and their effect on soil health evaluated. The present investigation deals with the effect of judicious apportioning of inorganic and organic nutrient inputs on crop productivity and some important soil health parameters in pigeonpea-wheat cropping system.

### MATERIALS AND METHODS

A field experiment on pigeonpea-wheat cropping system initiated in 2004 was continued during three consecutive years (2004-07). The sandy loam soil (*Typic Haplustept*) of the experimental field was well-drained, mild alkaline and non-saline, and initially contained 0.36% organic C, 194 kg/ha available N, 13.7 kg/ha avail-

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able P, 232 kg/ha available K and 7.2 mg/kg available S. In all, six treatments were evaluated in a randomized block design, which comprised of T<sub>1</sub>: Control (unfertilized), T<sub>2</sub>: NPK (60:60:40 & 120:60:40 kg/ha for pigeonpea and wheat, respectively), T<sub>3</sub>: FYM (2.5 t/ha in pigeonpea and 7.5 t/ha in wheat), T<sub>4</sub>: NPK+FYM (20:26:25 + 2.5t/ha in pigeonpea and 120:60:40 + 7.5 t/ha in wheat), T<sub>5</sub>: NPK+induced defoliation (ID) in pigeonpea using a foliar spray of 10% urea solution at physiological maturity (leading to a complete defoliation) and T<sub>6</sub>: NPK+FYM+ID. Extra-short duration pigeonpea 'ICPL 88039' and wheat 'HD 2285' were grown. During all the three years pigeonpea was sown in second week of June and wheat between 15 and 25 November, maintaining a row spacing of 60 cm and 20 cm, respectively. The standard agronomic practices recommended for pigeonpea and wheat were followed during the growing periods of crops. The crops were harvested at maturity manually from ground level, and the aboveground biomass was removed from the plots, except induced defoliation treatment. Grain and straw/stover samples were collected after recording the yields. The system productivity in terms of wheat grain equivalent and net returns computed by standard methods.

Post-harvest soil samples (0-15 cm depth) were also collected from all the plots after wheat. Soil samples were processed and analysed for organic C, available P, and K (Jackson, 1967) as well as biological properties *i.e.* Microbial biomass carbon (MBC) and Microbial biomass nitrogen (MBN) by fumigation method and dehydrogenase activity (Chhonkar *et al.* 2007). Bulk density were determined as per the method of Blake (1965). Water holding capacity of soil was determined by the Keen-Raczowski Box Method (Keen and Raczowski 1921). For these parameters, collection and processing soil cores/samples was done as per prescribed standard methods. Statistical analysis of data was subjected to 'F' test using the procedure for randomized block design (Gomez and Gomez, 1984).

## RESULTS AND DISCUSSION

### *Effect on crops yield and economics*

Application of fertilizer NPK at soil-test based recommended rates produced an average yield of 1.44 t/ha grain of pigeonpea, which was significantly higher than unfertilized-control (0.94 t/ha) and FYM alone and at par with that of NPK+ID. The grain yield with NPK+FYM was, on the other hand, significantly higher than all other treatments except the treatment having NPK+FYM+ID (Table 1). In wheat crop also, integrated use of NPK, FYM and ID gave higher grain yield (5.23 t/ha), which was significantly higher than that of all treatments except NPK+FYM (4.92 t/ha). Induced defoliation (ID) in pigeonpea using a foliar spray of 10% urea solution at physiological maturity

along with soil-test based NPK application appeared a better strategy as similar as application of 2.5 t/ha of FYM to pigeonpea and 7.5 t/ha to wheat along with soil-test based NPK. In addition, higher wheat equivalent grain yield was under NPK+FYM+ID across the year, even if we followed only ID with NPK or NPK+FYM that gives comparable wheat equivalent grain yield. The net returns of the system productivity were also greater under NPK+ID followed by NPK, which showed that ID is a better alternative for integrated plant nutrient supply system in place of FYM (Table 1). That also revealed higher profitability of NPK+ID, which was estimated some 20-30% and 30-40% more than that of NPK+FYM in pigeonpea and wheat respectively across the year.

Use of FYM in absence of fertilizers could produce only 1.15 t grain/ha average of pigeonpea and 3.02 t grain/ha of wheat, indicating clearly that the organics applied alone might not fully support high productivity levels. Highest wheat yields were registered under NPK+FYM+ID because of annual carbon and nutrient inputs were relatively higher in treatments involving FYM. The system productivity in terms of wheat grain equivalent was computed (Table 1) and revealed the adoption of induced defoliation in pigeonpea along with NPK+FYM gave the highest system productivity whereas significantly higher net returns (₹32,400/ha) was found under NPK+ID over the treatments, except NPK+FYM+ID. The additional net return was to the tune of ₹24,200/ha due to induced defoliation along with NPK over control. Studies on the effect of ID on crop yield, economics and soil properties are not many, yet limited available literature (Chauhan *et al.* 2001) supported the findings of this investigation.

### *Effect of induced defoliation*

Induced defoliation (ID) treatment imposed in pigeonpea led to an additional litter-fall of about 1.3 t/ha, through which about 41 kg N/ha was recycled, as estimated on the basis of its chemical analysis carried out. The effect of ID on pigeonpea yield was not visible, which is quite understandable. However, the same was very much apparent on the yield of succeeding wheat, as it accounted for wheat grain yield increase of 0.15 to 0.50 t/ha in NPK or NPK+ FYM treatments, owing to additional nutrient input (particularly N) and a marked improvement in important soil health parameters (Table 1). This additionally recycled biomass (leaf-litter) also increased the available N, P and K status of soil as compared to other treatments. Soil analysis showed significant increase in available nutrients, in the ID-based treatments, which was due to recycling of additional foliage of pigeonpea. Studies on the effect of ID on crop yield and soil properties are not many,

**Table 1.** Effect of integrated nutrient management on crop grain yields, productivity and net returns under pigeonpea-wheat cropping system

Treatment	Pigeonpea (t/ha)				Wheat (t/ha)				System productivity			Net return <sup>#</sup>		
	2004	2005	2006	Mean	2004-05	2005-06	2006-07	Mean	(t/ha) in terms of wheat grain equivalent			( $\times 10^3$ ₹/ha)		
									2004-05	2005-06	2006-07	PY	WY	SP
Control	0.98	0.94	0.89	0.94	2.55	2.21	1.88	2.21	4.35	4.08	3.29	7.6	0.6	8.2
NPK	1.44	1.39	1.50	1.44	4.62	4.24	3.98	4.28	7.15	7.48	6.57	13.5	17.2	30.7
FYM alone	1.25	1.04	1.14	1.15	3.42	3.16	2.48	3.02	5.70	5.24	4.28	3.3	1.6	4.9
NPK+FYM	1.69	1.82	1.87	1.79	5.03	5.00	4.74	4.92	8.12	8.64	7.69	11.3	13.5	24.8
NPK+ID	1.50	1.43	1.56	1.50	4.82	4.70	4.53	4.68	7.56	7.55	7.00	13.5	18.9	32.4
NPK+FYM+ID	1.61	1.77	1.89	1.76	5.30	5.35	5.03	5.23	8.24	8.89	8.01	9.7	16.6	26.3
SEm $\pm$	0.06	0.07	0.07	0.07	0.14	0.11	0.11	0.12	0.33	0.29	0.23	1.5	1.6	2.5
CD (P=0.05)	0.20	0.22	0.21	0.21	0.42	0.33	0.34	0.37	0.97	0.84	0.67	4.3	4.8	7.3

PY: pigeonpea yield, WY: wheat yield, SP: system productivity

<sup>#</sup>Price of pigeonpea and wheat in 2004-05: ₹13,900/t and ₹6,400/t, Price of pigeonpea and wheat in 2005-06: ₹14,000/t and ₹7,000/t, Price of pigeonpea and wheat in 2006-07: ₹14,100/t and ₹7,500/t

yet limited available literature (Chauhan *et al.* 2001) supported the findings of this investigation.

#### Effect on soil health

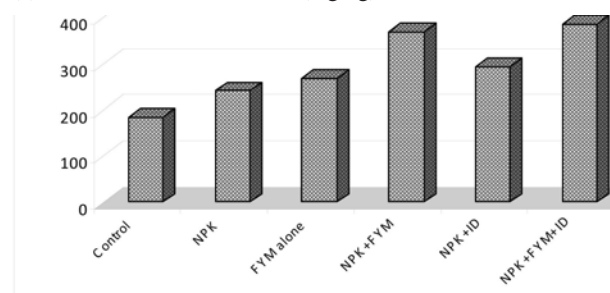
Soil health study including physical and biological parameters was made during the fourth consecutive year. Conjoint use of fertilizer NPK and FYM, improved soil physical health as revealed by a significant decrease in soil bulk density (BD) *vis-à-vis* sole fertilizer treatments or control (Table 2). Soil BD decreased from 1.56 Mg/m<sup>3</sup> in NPK to 1.40 Mg/m<sup>3</sup> in NPK+FYM+ID plots. Infact, NPK combination with FYM caused a significant drop in BD value. NPK plots that had a much BD as unfertilized control indicated that no appreciable amount of crop residue was recycled. Similar was the case with dehydrogenase activity (DHA), wherein all the treatments except NPK alone indicated significantly higher DHA over control (Fig. 2a). The highest value was noted in NPK+FYM+ID, closely followed by NPK+FYM. Among biological parameters of soil health, microbial biomass C (MBC), and microbial biomass N (MBN) were measured at panicle

**Table 2.** Effect of integrated nutrient supply on soil physical characteristics (wheat, 2006-07)

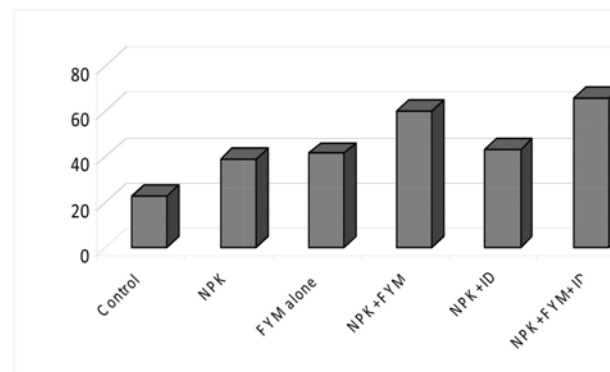
Treatment	Bulk density (Mg/m <sup>3</sup> )	Water holding capacity (%)
Control	1.57	35.2
NPK	1.56	35.1
FYM alone	1.45	35.6
NPK+FYM	1.42	39.3
NPK+ID	1.44	36.3
NPK+FYM+ID	1.40	38.5
SEm $\pm$	0.03	1.1
CD (P=0.05)	0.09	3.5
Initial	1.52	35.3

emergence in wheat (Figs. 1a and 1b). In general, highest values of these parameters were recorded in treatments that received NPK+ FYM, with or without ID. The reduction in BD and improvement in water holding capacity, MBC, MBN and DHA in these studies was, by and large, attributed to higher soil organic matter content, better aggregation and increased root growth in the fertilizer and manure treated plots (Hati *et al.* 2006; Rudrappa *et al.* 2006; Majumder *et al.* 2008 and Meena *et al.* 2008).

(a) Microbial biomass carbon (mg/kg)



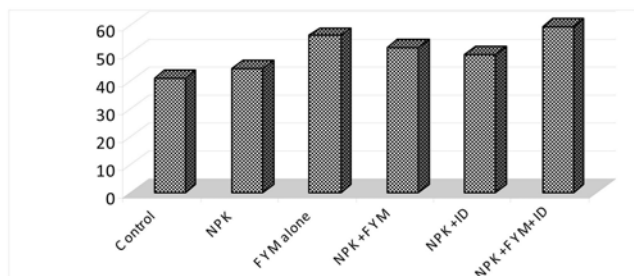
(b) Microbial biomass nitrogen (mg/kg)

**Fig. 1.** Effect of nutrient management options on MBC and MBN content of soil during wheat (2006-07)

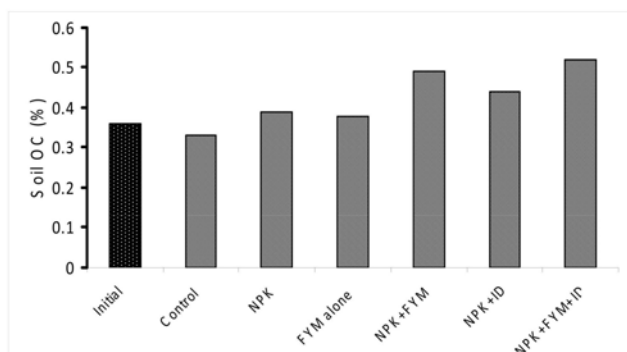
### Soil fertility status

Soil organic carbon (OC) content in the control plot showed only a marginal decline in comparison with the initial value of 0.36%, whereas the treatments receiving FYM along with NPK recorded significantly greater OC content (Fig 2b). Induced defoliation (ID) too enhanced soil OC similar to NPK+FYM treatment. On completion of three cropping cycles, a significant increase in available N, P and K was recorded in the treatments where fertilizer NPK was applied in combination with FYM. The available N in different treatments varied from 221 to 265 kg/ha with an average value of 238 kg/ha, available P varied from 12.9 to 27.9 kg/ha with an average of 20.2 kg/ha and available K varied from 223 to 281 with an average value of 241 kg/ha, against the initial values of 194, 13.9 and 232 kg/ha of available N, P and K, respectively. The highest values of available N, P and K were observed in the treatments where induced defoliation with fertilizer NPK+FYM. The ID resulted in of 1.2 to 1.4 t/ha additional leaf-litter recycling over the natural senescence in other (non-ID) treatments. Substantial increase in soil mineral N contents particularly in surface layer under ID (Fig. 3) is very much expected, for the additional leaf litter recycled in this treatment not only added about 41 kg N/ha but also the N and other nutrients contained therein were possibly released faster (due to narrow C/N ratio) com-

(a) Dehydrogenase activity ( $\mu\text{g TPF}/24 \text{ h/g soil}$ )

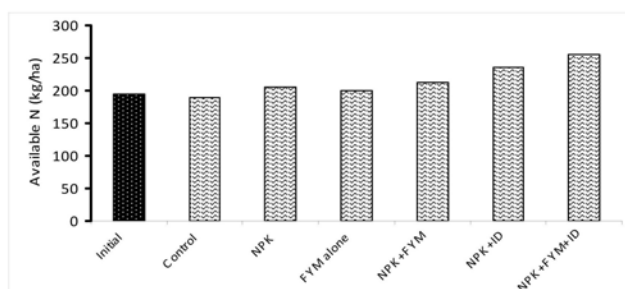


(b) Soil organic carbon (%)

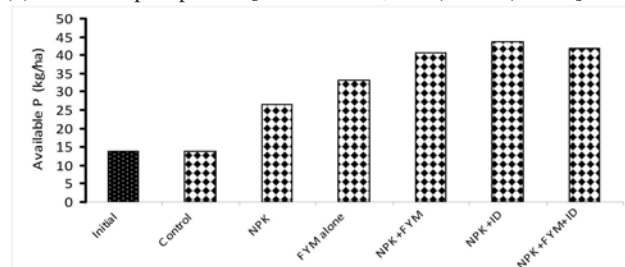


**Fig. 2.** Soil dehydrogenase activity [ $\text{SEM} \pm = 0.1$ ,  $\text{CD} (P=0.05) = 0.5$ ] and soil organic carbon [ $\text{SEM} \pm = 0.01$ ,  $\text{CD} (P=0.05) = 0.04$ ] as influenced by integrated nutrient supply during wheat (2006-07)

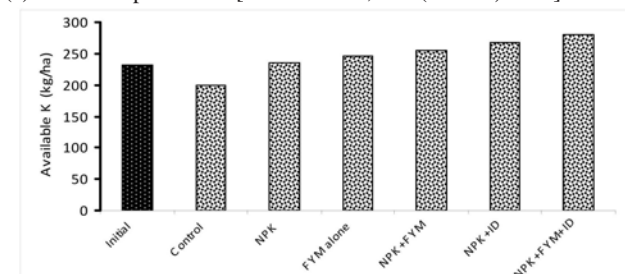
(a) Available nitrogen [ $\text{SEM} \pm = 5.1$ ,  $\text{CD} (P=0.05) = 15.4$ ]



(b) Available phosphorus [ $\text{SEM} \pm = 1.6$ ,  $\text{CD} (P=0.05) = 4.7$ ]



(c) Available potassium [ $\text{SEM} \pm = 9.7$ ,  $\text{CD} (P=0.05) = 30$ ]



**Fig. 3.** Effect of nutrient management options on available nutrient content of soil after wheat (2006-07)

pared with FYM. Studies on the effect of ID on crop yield and soil properties are not many, yet limited available literature (Chauhan *et al.* 2001) supported the findings of this investigation. Highest wheat yields and other nutrient contents were registered under NPK+FYM+ID.

It is inferred that the soil-test based NPK resulted significantly higher grain yield of pigeonpea and wheat compared with sole manure treatments. Integration of fertilizer with FYM and ID appeared superior to sole fertilizers or manures. Conjoint use of fertilizer NPK and FYM improved soil health as revealed by a lower bulk density and higher MBC, MBN, DHA and water holding capacity *vis-à-vis* sole fertilizer treatments or unfertilized control.

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