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Effect of intercropping *in-situ* green manures and fertility levels on productivity and soil nitrogen balance in maize (*Zea mays*)–gobhi sarson (*Brassica napus*) cropping system*

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Maize (*Zea mays* L.)—wheat(*Triticum aestivum* L. emend. Fiori & Paol) is the most predominant cropping system in Himachal Pradesh covering 40% of area. Gobhi sarson (*Brassica napus* L.) has emerged as potential replacement for wheat due to wider adaptability and suitability to exploit the rainy *(kharif)* residual moisture. Increase in productivity of maize-based cropping system with integrated use of farmyard manure and chemical fertilizer has been widely reported (Kumpawat 2004 and Jamwal 2005). Inclusion of legumes in cropping system significantly contributes to nitrogen economy and reduces energy inputs. The legumes can be included as an intercrops either for *in-situ* green manuring or as a grain crop for studying the residual effect on fertility. Information on legumes intercropping as *in-situ* green manure in maize-based cropping system is very scanty. Hence, a study was undertaken on intercropping *in- situ* green manures in combination with fertility levels for chemical fertilizer economy in maize-gobhi sarson cropping system.

The experiment was conducted under rainfed conditions at Oilseeds Research Station, Kangra, Himachal Pradesh located at an elevation of 700 m above msl having latitude of 32°05'N and longitude 76°18'E during 2004–07. The soil of experimental site was silty clay loam, having *p*H 6.2, available nitrogen 196.4 kg/ha, available phosphorus 13.7 kg/ha and available potassium 129.6 kg/ha. Five intercropping systems, viz maize pure, maize + soybean, maize + cowpea as *in situ* green manure, maize + cowpea as grain crop and maize + *Crotolaria* as *in situ* green manure in all possible combinations with 3 fertility levels, viz 50%, 100% RDF through inorganics (120 kg N + 26.4 kg P + 33.2 kg K/ha) and 50% RDF through inorganics + 50% RDF through FYM only during *kharif* season were arranged in randomized block design with 3 replications. The plots were fixed for the 3 years. Maize 'Rani' was sown in rows 60 cm apart with plant-to-plant spacing of 15 cm during first to second week of June. The legume intercrops were sown in between the 2 maize rows with recommended fertilizer on area basis soybean (20 kg N + 26.4 kg P + 33.2 kg K/ha), cowpea (20 kg N + 17.6 kg P + 24.9 kg/ha), crotolaria (20 kg N + 17.6 kg P + 24.9 kg K/ha). Cowpea and *Crotolaria juncea* as green manure was incorporated at 35–40 days stage. In *rabi* season the plots were divided into 2 parts, i e control and recommended 90 kg N + 26.4 kg P + 33.2 kg K/ha as treatment in gobhi sarson. The gobhi sarson 'Neelam' was sown in rows 30 cm apart during last week of October to first week of. Pendemethalin in maize and Isoproturon in gobhi sarson with one hand weeding were followed to control weeds. The FYM (0.50–0.52:0.19–0.24:0.42–0.49% N: P: K) of 30–35% moisture content was applied on air dry weight basis at sowing by thorough mixing with soil. Nitrogen as per treatments was applied in 3 splits in maize (50% at sowing, 25% at knee high stage and 25% at silking stage) in maize and 2 splits (50% at sowing and 50% at 30–35 days after sowing) in gobhi sarson. Phosphorus and potassium to both crops was applied as basal dose. Total rain fall of 1484.7 mm, 1327.6 mm and 2635.1 mm was received during *kharif* and 506.7 mm, 208.7 mm and 344.6 mm during *rabi* in respective years of cultivation. The grain and straw samples were analyzed for N, P and K using standard analytical procedures and uptake was calculated. Soil samples at harvest of third cycle was analyzed for available N. Nutrient balance in soil was calculated as: v-(X-a)-N,where v is the nutrient removed by crops is the initial soil status of the nutrient element;a is the final soil status of the nutrient element and N is the nutrient added through fertilizer (Raghuvanshi *et al.*1991). The economic analysis was made considering the prevailing market costs of inputs and prices of output.

Cropping systems followed and fertility levels significantly influenced the maize yield attributes and yields.

*Short note

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Table 1 Direct effect of cropping system and fertility levels on maize in maize–gobhi sarson cropping system (pooled data of 3 years)

	Cobs ('000/ha)	Grains/ cob	1000-grain weight (g)	Maize grain yield (tonnes/ha)				Maize equivalent (tonnes/ha)	Maize returns ($\times 10^3$ Rs/ha)
				2004	2005	2006	Mean		
Cropping systems									
Maize pure	43.1	348	275.4	3.86	2.93	5.48	4.13	4.13	22.61
Maize + soybean	48.5	391	276.2	4.21	5.05	6.45	5.24	5.93	30.37
Maize + cowpea (GM)	50.1	394	276.8	5.30	4.58	6.47	5.45	5.45	31.32
Maize + cowpea (grain)	35.9	348	273.2	2.37	2.57	5.32	3.42	4.27	20.55
Maize + crotolaria (GM)	48.2	392	276.4	4.89	4.42	6.32	5.21	5.21	28.52
SEm±	0.85	4.95	0.33	0.52	0.15	0.19	0.10	0.11	
CD (*P*=0.05)	1.7	10.2	0.67	1.07	0.31	0.39	0.21	0.23	
Fertility levels									
50% RDF (inorganics)	41.9	358	275.3	3.39	3.22	5.78	4.15	4.41	23.80
50% RDF (inorganics) + 50% organics	45.4	374	275.7	4.08	4.01	5.99	4.70	5.00	22.48
100%RDF (inorganics)	48.2	392	275.8	4.92	4.50	6.24	5.22	5.58	33.93
SEm±	0.66	3.84	0.25	0.15	0.07	0.07	0.08	0.09	
CD (*P*=0.05)	1.4	7.9	NS	0.31	0.15	0.15	0.17	0.18	

Maize + cowpea (green manure) and maize + soybean system being statistically at par with maize yield attributes values of number of cobs/ha, grains/cob and 1 000-grain weight produced significantly higher maize grain and straw yield over all other system (Table1). The increase in yield over maize pure system was 31.9 and 26.9%, respectively. The maize + *Crotolaria* (GM) system also produced 26.2% higher yield over maize pure system. The lowest maize yield (3.42 tonnes/ha) was recorded in maize + cowpea (grain) system where shading by cowpea significantly reduced the effective cobs number/ha. Data also revealed that application of 100% RDF through inorganic source significantly improved the grain yield of maize by 42.6 and 50.9% over 50%RDF and 50%RDF inorganics + 50% organics, respectively. The difference between inorganic and integrated source may be attributed to time of release and availability for crop.

Maize + soybean intercropping system due to additional yield of intercrop produced the highest maize equivalent yield (5.93 tonnes/ha) and it was 43.6, 13.8 and 8.8% higher over maize pure, maize + *Crotolaria*(GM) and maize + cowpea (GM) systems, respectively. Recommended dose of fertilizers application through inorganic source only gave 26.5 and 11.6% higher maize equivalent yield over 50% RDF inorganics and 50% RDF(inorganics) + 50% (organics) treatments, respectively.

Residual effect of intercropping system followed in *kharif* season on succeeding gobhi sarson was significant, whereas the fertility levels did not differ significantly. Significantly highest number of primary and secondary branches/plant, pods/plant and 1000-grain weight and seed yield (1.33tonnes/ha) were obtained when gobhi sarson was preceded by maize + cowpea (grain) intercropping system (Table 2).This was followed by seed yields of 1.23tonnes/ha and 1.15tonnes/ha when preceded by maize + soybean and maize + *Crotolaria* (GM) system,respectively. The per cent increase in seed yield of gobhi sarson by preceded maize + cowpea (grain) intercropping system was 30.4 and 8.1% over maize pure and maize + soybean system, respectively.

Averaged over all the *kharif* season treatments the recommended fertilizer application in gobhi sarson resulted in 93.7% increase in seed yield over no fertilizer application. With no significant interaction between intercropping system, fertility levels applied in *kharif* and fertility application in *rabi* season it leads to indication that the residual effect of these legume and fertility levels applied in *kharif* crop is not appreciable and the succeeding gobhi sarson crop needs full dose of fertilizer to give optimum yields. Thakur *et al.* (2003) and Kumar *et al.* (2004) also reported response by gobhi sarson to recommended nitrogen level when sown after organics and higher fertility levels in *kharif*.

Intercropping system followed and fertility levels applied in preceding *kharif* season significantly influenced the maize-gobhi sarson cropping system total productivity in terms of maize equivalent yield. Significantly highest system productivity (25.2 kg/ha/day) was recorded under maize + soybean gobhi sarson cropping system (Table 2). This was followed by maize + cowpea (GM) and maize + *Crotolaria* (GM) system, respectively. There was increase of 34.5, 22.1 and 20.9% in productivity compared to pure maize crop system in *kharif*. Recommended fertilizer application in *kharif* season increased the total productivity of cropping system by 18.1 and 7.1% over 50% RDF (in organics) and 50%RDF(inorganic) + 50 organics treatments, respectively. Averaged over preceding *kharif* season treatments the recommended fertilizer application in succeeding gobhi

Table 2 Residual effect of cropping system and fertility levels applied in maize and direct effect of fertility levels in gobhi sarson on gobhi sarson, total productivity and economics of maize-gobhi sarson system (pooled data 3 years)

Treatment	Primary branches/ plant	Secondary branches/ plant	Pods/ plant	Seeds/ pod	1000-grain weight (g)	Seed yield (tonnes/ha)				System producti-vity (kg/ha/ day)	System profita-bility (Rs/ha/ day)	B:C ratio
						2004–05	2005–06	2006–07	Mean			
In maize												
Cropping systems												
Maize pure	4.7	1.0	164	24.2	2.91	0.85	0.81	1.40	1.02	18.73	98	2.11
Maize + soybean	5.5	1.2	187	23.2	2.96	1.21	0.99	1.47	1.23	25.19	141	2.74
Maize + cowpea(GM)	5.3	1.1	170	24.3	2.91	1.05	0.83	1.38	1.08	22.87	126	2.45
Maize + cowpea(grain)	5.8	1.3	192	24.4	2.97	1.18	1.25	1.54	1.33	21.39	109	2.15
Maize + crotolaria(GM)	5.5	1.2	175	24.9	2.95	0.97	0.94	1.53	1.15	22.65	121	2.25
SEm±	0.05	0.03	4.9	0.23	0.01	0.05	0.07	0.06	0.04	0.41		
CD(*P*=0.05)	0.09	0.06	9.7	0.5	0.02	0.09	0.15	0.12	0.08	0.83		
Fertility levels												
50% RDF	5.2	1.1	174	23.8	2.93	1.00	0.93	1.42	1.12	20.25	112	2.64
50% RDF + 50% organics	5.4	1.2	179	24.1	2.94	1.10	0.97	1.47	1.18	22.33	106	1.66
100%RDF	5.5	1.2	180	24.8	2.94	1.04	0.99	1.51	1.18	23.93	138	3.04
SEm±	0.04	0.02	3.8	0.18	0.01	0.04	0.06	0.05	0.03	0.32		
CD(*P*=0.05)	0.07	0.05	NS	0.4	NS	0.07	NS	NS	NS	0.64		
In gobhi sarson												
No fertilizer	4.0	0.8	113	23.2	2.91	0.62	0.67	1.09	0.79	19.46	101	2.09
Recommended fertilizer	6.7	1.6	242	25.3	2.97	1.48	1.26	1.84	1.53	24.87	136	2.57
SEm±	0.03	0.02	3.1	0.15	0.01	0.03	0.05	0.04	0.03	0.26		
CD (*P*=0.05)	0.05	0.04	6.2	0.3	0.01	0.06	0.09	0.08	0.05	0.52		

MEY, Maize equivalent yield

sarson crop increased the productivity by 27.9% over no fertilizer application.

Significantly highest N uptake in maize was observed in maize + soybean intercropping, followed by maize + cowpea (GM). The P and K uptake was statistically equal in maize + soybean and maize + cowpea (GM) intercropping system (Table 3). Significant increase in NPK accumulation was observed when fertility level was increased from 50%RDF to 100% RDF.

Higher nutrient accumulation in gobhi sarson crop was observed when it was preceded by maize + cowpea (grain) intercropping, followed by uptake in maize + soybean system. The leaf biomass as litter added by cowpea and soybean added to the nutrient pool of soil. Application of recommended fertilizer application in preceding *kharif* season resulted in significant higher N and K uptake as compared to 50% RDF application. Averaged over *kharif* season treatments recommended fertilizer application in gobhi sarson compared to no fertilizer application recorded higher N(124.7%), P(102.9%) and K(133.7%) uptake.

Significantly highest N and P uptake (247.2 kgN and 56.4 kg P/ha) was observed in maize + soybean- gobhi sarson cropping system. This was followed by maize + *Crotolaria* (GM)-gobhi sarson and maize + cowpea (GM)-gobhi sarson system. The K uptake was statistically at par with all the above cropping system. Increasing the fertility level from 50%RDF to 100% RDF significantly increased the nutrient uptake. Averaged over *kharif* season treatments the recommended fertilizer application in gobhi sarson compared to no fertilizer application resulted in higher N (22.6%), P (23.8%) and K (15.7%) uptake.

Additional soybean yield without loss of maize crop in maize + soybean intercropping as preceding *kharif* succeeded by gobhi sarson resulted in highest system profitability (Rs 141/ha/day) and B:C ratio(2.74) (Table2).This was followed by system profitability when gobhi sarson was preceded by maize + cowpea (GM)(Rs 126.1/ha/day). These returns were Rs 43 and Rs 28 higher than system where maize pure crop was the preceding crop to gobhi sarson. Recommended

Table 3 Effect of cropping system and fertility levels in maize-gobhi sarson sequence on nutrient uptake (kg/ha) and balance sheet of N in soil (pooled data 3 years)

	Maize			Gobhi sarson			Maize + gobhi sarson			N balance sheet (kg/ha)		
	N	P	K	N	P	K	N	P	K	Total N applied *kharif* + *rabi*	Residual N after gobhi sarson harvest	N balance
In maize												
Cropping systems												
Maize pure	113.8	27.5	137.9	49.9	13.2	30.1	163.7	40.7	167.9	145	179	1.3
Maize + soybean	186.9	40.2	180.4	60.3	16.2	37.6	247.2	56.4	217.9	165	188	72.7
Maize + cowpea(GM)	152.9	38.8	183.7	54.6	14.4	33.6	196.3	53.2	217.4	195	195	14.3
Maize + cowpeagrain)	103.2	25.2	115.7	64.8	17.4	40.1	168.0	42.6	155.8	165	198	1.9
Maize + crotolaria(GM)	145.1	36.3	175.6	56.1	15.4	34.5	201.3	51.8	210.1	210	198	–7.4
SEm±	3.3	0.9	3.8	1.8	0.7		8.3	1.0	3.1			
CD(*P*=0.05)	6.7	1.8	7.8	3.7	1.3	2.4	16.5	2.0	6.1			
Fertility levels												
50% RDF	121.5	28.8	140.3	54.8	14.9	33.6	176.3	43.7	173.9	136	186	31.7
50% RDF + 50% organics	140.9	34.0	158.8	58.4	15.5	36.3	192.7	49.6	195.1	196	196	2.3
100%RDF	158.6	37.9	176.8	58.3	15.6	35.7	216.9	53.5	212.5	196	193	15.8
SEm±	2.5	0.7	2.9	1.5	0.4	1.0	6.4	0.8	2			
CD(*P*=0.05)	5.2	1.4	6.0	2.9	NS	1.9	12.8	1.6	4.8			
In gobhi sarson												
No fertilizer				35.2	10.1	21.1	175.5	43.7	179.7	130.9	184.9	34.9
Recommended fertilizer				79.1	20.5	49.3	215.1	54.1	207.9	220.9	197.8	0.32
SEm±				1.2	0.4	0.8	5.2	0.6	1.9			
CD (*P*=0.05)				2.3	0.8	1.5	10.5	1.3	3.9			

fertilizer application in preceding *kharif* resulted in highest system profitability (Rs 138/ha/day) for the cropping systems. The integrated nutrient treatment of 50%NPK + 50% through FYM gave the lowest returns ascribed to higher cost of organics to meet out the 50% requirement. Direct application of recommended fertilizer over no fertilizer in gobhi sarson increased the system profitability by Rs 35/ha/day

Soil available N content as compared to initial soil N status did not differ much when maize + cowpea (grain)–gobhi sarson, maize + cowpea (GM)-gobhi sarson and maize + *Crotolaria* (GM)-gobhi sarson cropping system was followed (Table 3), whereas in maize pure-gobhi sarson and maize + soybean–gobhi sarson there was depletion of available N content by 17 and 9 kg/ha, respectively.

Nitrogen did not find proportionate exhibition in balance sheet in the form of available N in the soil. The negative N balance (–7.4 kg/ha) was observed in maize + *Crotolaria*(GM)intercropping system was preceding *kharif* crop indicating that N removed by crops in system was less than the added. However, with all other preceding intercropping systems there was positive N balance with highest in maize + soybean (72.7 kg/ha), followed by maize + cowpea (GM) (14.3 kg/ha). This showed that nutrient removed by these cropping system was more than the applied one. Application of 50% RDF resulted in decrease in soil available N content by 10 kg/ha and maximum gain of N (31.7 kg/ha) indicating drain on soil native pool. Application of recommended nutrient through integrated source of 50%NPK through inorganic + 50% organics showed the lower N gain value(2.3 kg/ha) compared to inorganic source only(15.8 kg/ha). Beneficial effect of FYM on sustainable balance for maize based cropping system has been reported (Pathak *et al.* 2005, Jamwal *et al.* 2005). Recommended fertilizer application to gobhi sarson in system resulted in soil available N almost same at initial level and at the same time the N balance was also static (0.32), whereas escaping fertilizer resulted in positive soil N balance (34.9), indicating drain on native soil

Thus it is concluded that following maize + soybean or maize + cowpea (green manure) intercropping during *kharif* helped realize sustained productivity and profitability of the maize–gobhi sarson cropping system. Further application of recommended dose of fertilizer is necessary for both maize and succeeding gobhi sarson crop.

SUMMARY

The experiment was conducted during 2004–07 under rainfed conditions at Oilseeds Research Station, Kangra Himachal Pradesh to know the effect of legume intercropping and fertility levels on productivity and nitrogen balance in

soil in maize–gobhi sarson sequence. Maize + cowpea (GM), maize + soybean and maize + crotolaria (GM) intercropping system being at par gave 31.9, 26.9 and 26.2% higher maize yield over maize sole system. Significantly highest gobhi sarson seed yield was obtained when preceded by maize + cowpea grain (1.33tonnes/ha) and maize + soybean (1.23tonnes/ha). Maize responded to 100% fertility level application (5.22tonnes/ha); residual effect on succeeding gobhi sarson did not differ significantly. Direct application of recommended fertilizer in gobhi sarson increased the seed yield by 93.7%. Significantly highest system productivity (25.2 kg/ha/day), system profitability (Rs 141.3/ha/day) and B:C ratio(2.74), and uptake were observed in maize + soybean–gobhi sarson system followed maize + cowpea (GM)–gobhi sarson system (22.9 kg/ha/day and Rs 126.1/ ha/day). The balance sheet of N showed that there was maximum gain of N in maize + soybean–gobhi sarson sequence followed by maize + cowpea (GM)–gobhi sarson sequence. Application of 50% RDF in *kharif* showed the maximum gain of N in balance sheet, whereas the integrated treatment of 50%NPK + 50% organics showed the lowest.

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CORRECTION

In Vol. **79**, issue 5 on page 395 in Table 1, data may please be read as:

Parents	Harvest index						RWC (%)			DSI			Proline content					
	E_1			E_2			E_2						E_1			E_2		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
'PWB 175'	0.97	0.91	0.94	0.71	0.65	0.68	4.11	3.61	3.86*	0.02	0.02	0.02	0.15	0.07	0.11*	0.17	0.11	0.14*

In column *Parents* S.E. (”i) and S.E. (”i–”i) may please be read as S.E. (ĝi) and S.E.

In Vol. **79**, issue 7 on page 527, the authors of the article validation and popularization of integrated pest management technology in cotton (*Gossypium hirsutum*) may please be read as O P Ameta[1], G K Bunker[2] and O M Bambawale[3] in place of O P Ameta[1] and G K Bunker[2]