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Nutrient management and productivity of wheat (*Triticum aestivum*)–based cropping systems in temperate zone

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ABSTRACT

An experiment was carried out from winter season of 2004-05 to rainy season of 2006 at Srinagar to determine the impact of different nutrient management practices and cropping systems on growth, yield, nitrogen uptake and system productivity of wheat [*Triticum aestivum* (L.) emend Fiori & Paol]– based cropping systems. Treatments consisted of four fertility levels *viz.* recommended fertilizer dose (100 kg N + 60 kg P_2O_5 + 30 kg K_2O/ha), recommended fertilizer dose + farmyard manure 15 tonnes/ha; recommended fertilizer dose + biofertilizer and recommended fertilizer dose + farmyard manure 15 tonnes/ha + biofertilizer applied to wheat crop and six crop sequences, *viz.* wheat – rice (*Oryza sativa* L.), wheat – maize (*Zea mays* L.); wheat – sunflower (*Helianthus annuus* L.); wheat – greengram [*Vigna radiata* (L.) Wilczek], wheat – soybean [*Glycine max* (L.) Merrill] and wheat – Frenchbean (*Phaseolus vulgaris* L.). Combined application of recommended fertilizer dose, farmyard manure 15 tonnes/ha and biofertilizer significantly improved wheat yield and soil nutrient status. Increase in wheat yield was to the tune of 17.5 and 23.0% over the alone application of chemical fertilizer during 2004-05 and 2005-06 respectively. Wheat yield and nitrogen uptake showed significant increase when grown after pulses. Yield improvement in wheat was 11 and 10% due to legume effect of greengram and Frenchbean respectively. Wheat-rice sequence proved more productive and remunerative cropping system.

***Key words*:** Nutrient sources, Productivity, Profitability, Wheat-based cropping systems.

Rice–wheat cropping system is considered back bone of food security in India, which is followed in 10.5 million hectare area (Yadav *et al.* 2005). Country is striving hard for 2nd green revolution. In this direction efforts are underway to popularize wheat as winter (*rabi*) crop preferable under rice-wheat cropping system in the temperate zone of Jammu and Kashmir state. In Kashmir valley, harsh conditions during winter season check wheat growth like other *rabi* seasons crops (Mubarak and Singh, 2009). Climate delays maturity of wheat, which often posses problem in the transplanting of succeeding rice. This not only reduces rice yield but also decreases the overall productivity of rice-wheat cropping system. Moreover, both these crops are exhaustive in nature and put pressure on nutrient sources (Gupta *et al.,* 2006). Studies further show that inclusion of legumes in cropping system improves soil fertility (Lupwayi and Kennedy, 2007), thereby increasing the yield of succeeding crop. There is need to evaluate a sustainable wheat – based cropping system for the Kashmir valley. With this objective, the present investigation was carried out to study the effect of different fertilizer management practices and preceding *kharif* season crops on succeeding wheat and overall system productivity.

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MATERIALS AND METHODS

The field experiment was conducted in a fixed plot design during 2004-06 at Srinagar, which is situated between 34°.05' N latitude and 74°.89' E longitude at an altitude of 1,587 m above mean sea level. Soil was silty clay loam in texture having 1.4% coarse sand 19.3% fine sand, 47.7% silt and 31.6% clay with pH 6.93, organic carbon 0.68%, available nitrogen 266.8 kg/ha, phosphorous 21.5 kg /ha and potassium 215 kg/ha. The annual precipitation during crop cycle was 999.6 and 861.1 mm during 2004-05 and 2005-06 respectively. The experiment was conducted in a three times replicated split– plot design, where wheat received four fertility levels *viz.* Recommended dose of fertilizer (RDF) (100 kg N + 60 kg P_2O_5 + 30 kg K_2O/ha); RDF + farmyard manure 15 tonnes/ha; RDF + biofertilizer (combination of *Azospirillum, Azotobacter* and *phosphate solubilizing bacteria (*PSB); 1 kg/ha; and RDF + farmyard manure 15 tonnes/ha + biofertilizer in main plots and six crop sequences *viz.* wheat–rice; wheat–maize; wheat–sunflower; wheat–greengram; wheat–soybean; wheat–Frenchbean allocated in sub plots. The N, P and K contents of FYM were 0.71, 0.22 and 1.07% (2004-05) and 0.73, 0.26 and 1.09 (2005-06), respectively. *Azotobacter, Azospirillum* and PSB were used as a seed treatment in wheat crop. A sugar solution (10%) was heated for 15 minutes and then cooled at room temperature. Biofertilizer was mixed with it to form slurry. Seeds were added to the slurry and thoroughly mixed by hand. Treated seeds were dried in shade and sown. During 2004-05, wheat crop was sown and harvested on 23 October and 10 June, respectively. During 2005-06, wheat crop preceded by rice, sunflower, greengram and Frenchbean was sown and harvested on 17 October and 2 June, respectively, while in wheat-maize and wheat-soybean cropping sequences it was sown and harvested on 29 October and 6 June, respectively. Wheat crop was irrigated at grain filling stage during both the years. Alternate wetting and drying was followed in rice crop. Rest of the rainy season crops were irrigated as and when required, especially at flowering stage. The details of the production technology adopted for different cropping sequences are given in (Table 1). Ten random plants were selected from each plot, excluding the border row, for taking observation on growth and yield attributes of wheat. The representative dry samples of shoot and seed were analyzed for ascertaining nitrogen content using Modified Kjeldahl's method.

RESULTS AND DISCUSSION

Effect on growth attributes of wheat

Growth parameters of wheat, *viz.* plant height, tiller number, leaf area index and dry matter accumulation significantly increased with integration of different sources of nutrients (Table 2). Combined application of recommended dose of fertilizer (RDF) + farmyard manure (FYM) 15 tonnes/ha + biofertilizer recorded higher values for growth parameters followed by RDF + FYM 15 tonnes/ha, during both the years. This may be attributed to the improvement in soil fertility due to use of chemical fertilizer in conjugation with organic and biological sources of nutrients. Similar results were also reported by Sarma *et al.* (2007). The margin of difference with respect to crop growth between the different fertility levels was less during initial growth stages and then increased remarkably during the advanced stages of crop growth (Fig 1). It may be due to mineralization of organic manure and increased activity of biofertilizers under suitable temperature regime during the advanced stages of crop growth. Biofertilizer in the absence of FYM could not produce significant variation in any of the growth parameters. Combination of biofertilizers with recommended dose of NPK + FYM 15 tonnes/ha, significantly increased the growth characters owing to the availability of sufficient substrate for faster microbial activity with simultaneous release of nutrients for the use of crop plants (Jayab *et al.* 2001). Pulses on the whole proved more efficient in delivering beneficial residual effect to succeeding wheat. Significantly taller plants, more tillers, higher leaf area and dry matter was recorded in treatments where wheat was preceded by leguminous crops than the crop grown after cereals and oilseed (Table 2 and Fig 2). This might be due to residual effect of legumes on succeeding crop of wheat.

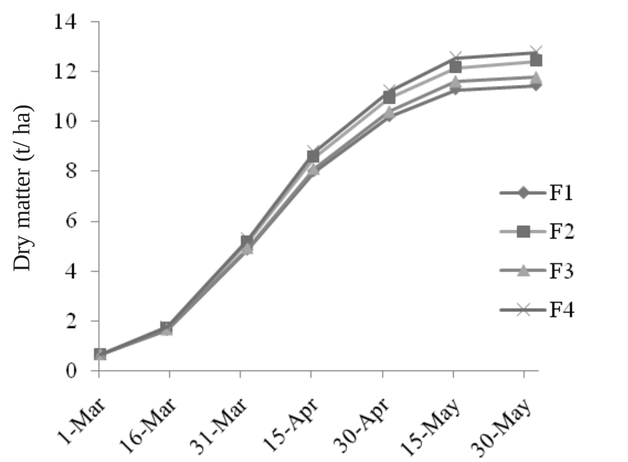

Fig 1. Periodic dry matter accumulation in wheat under different fertility levels

Table 1. Production technology adopted for different crops.

Season	Crop	Variety	Spacing	Recommended dose of fertilizer (kg/ha)		
				N	P_2O_5	K_2O
Winter	Wheat	'HS-240'	23 cm	100	60	30
Rainy	Rice	'Shalimar Rice 1'	15 cm x 15 cm	80	45	20
Rainy	Maize	'C_6'	60 cm x 20 cm	90	60	30
Rainy	Sunflower	'Morden'	70 cm x 30 cm	60	90	40
Rainy	Greengram	'M-86'	30 cm x 10 cm	30	50	20
Rainy	Soybean	'PS –1092'	40 cm x 10 cm	80	50	50
Rainy	Frencbean	'Canadian red'	22 cm x 45 cm	30	50	50

These results are in conformity with those of Balyan (1997).

Effect on yield attributes and yield of wheat

Yield attributes, such as number of ears/m^2, grains/ear and ear weight was significantly higher with integration of chemical, organic and biological sources of nutrients. Significant improvement in grain and straw yield was also observed with combine application of recommended dose of NPK + FYM 15 tonnes/ha and biofertilizer, which sustained better growth, produced better yield attributes and ultimately higher grain yield. Increase in grain yield was to the tune of 17.5 and 23% over the alone application of RDF during 2004-05 and 2005-06 respectively. The above findings are in close conformity with those of Ram and Mir (2006). Application of organic manure produced more pronounced effect on crop yield in the second year of experimentation in comparison to the first year. This possibly may be due to residual effect and priming effect. Biofertilizer again failed to bring significant improvement in grain and straw yield in the absence of farmyard manure in treatment receiving recommended dose of NPK + biofertilizer.

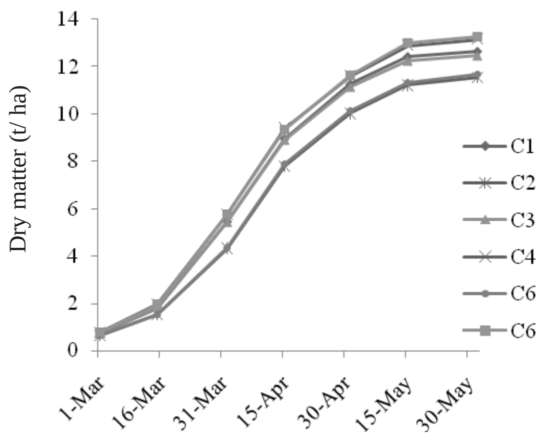

Fig 2. Periodic dry matter accumulation in wheat under different cropping sequences

Significant improvement in yield attributes were recorded in wheat crop when raised after greengram and Frenchbean. Wheat preceded by rice, maize and sunflower produced significantly lower values of yield attributes particularly with respect to maize-wheat sequence, owing to exhaustive nature and delayed maturity of maize crop, which in turn delayed sowing of wheat. Wheat grain and straw yield showed significant variation due to preceding rainy season crops (Table 3). Grain yield of wheat increased significantly by 11 and 10%, when grown after greengram and Frenchbean, respectively in the second year as compared to first year, presumably due to utilization of nitrogen fixed by preceding leguminous crops. The beneficial effect of legumes on the succeeding crop has also been reported by Miller *et al.* 2003. Soybean could not improve yield of succeeding wheat crop because it delayed sowing of wheat. Delayed sowing drastically reduces grain yield of wheat (Chatrath and Singh, 2010). The exhaustive nature of cereals and oilseeds may be the reason for reduced yield of wheat after sunflower, soybean and rice as compared to greengram and Frenchbean.

Table 2. Wheat crop growth as influenced by fertilizer management and residual effect of preceding crop

Treatment	Plant height at maturity (cm)		Tillers/m^2 (Booting stage)		Leaf area index (Booting stage)		Dry matter at maturity (t/ha)	
	2005	2006	2005	2006	2005	2006	2005	2006
Fertility level								
RDF	105	104	674	722	4.74	4.81	11.4	12.0
RDF + 15 t FYM	109	112	722	759	5.00	5.13	12.4	12.6
RDF + Bio-fertilizers	107	106	679	743	4.80	4.90	11.7	12.2
RDF + 15 t FYM + Bio-fertilizers	113	115	752	777	5.12	5.26	12.7	13.0
SEm±	0.2	0.3	1.8	3.0	0.01	0.02	0.44	0.79
CD (P=0.05)	0.8	1.0	6.2	10.3	0.03	0.06	1.53	2.62
Cropping sequence								
Wheat–rice	108	108	710	745	4.90	5.09	12.1	12.6
Wheat–maize	107	101	705	734	4.94	4.75	12.1	11.5
Wheat–sunflower	109	109	705	740	4.92	5.04	12.0	12.5
Wheat–greengram	109	114	709	763	4.91	5.25	12.1	13.1
Wheat–Frenchbean	109	105	707	753	4.90	4.83	12.2	11.7
Wheat–soybean	109	112	704	765	4.92	5.20	12.1	13.3
SEm±	0.5	0.3	2.4	2.8	0.03	0.02	0.80	1.36
CD (P=0.05)	NS	0.8	NS	8.0	NS	0.06	NS	4.72

RDF: 100 N + 60 P_2O_5 + 30 k_2O kg/ha; *Bio-fertilizers*: *Azotobacter* + *Azospirillum* + PSB

Nitrogen uptake by wheat

Combined application of RDF + FYM 15 tonnes/ha + biofertilizer recorded significantly higher nitrogen uptake followed by application of FYM 15 tonnes/ha along with RDF. This may be attributed to the increased grain and straw yield of crop and their respective nutrient contents owing to increased availability of nutrients to the crop as a result of improved soil fertility. Farmyard manure acts as a nutrient reservoir and releases nutrients slowly, expected to be more closely matched with supply and demand by the crop. These results confirm the findings of Patidar and Mali (2001) and Brar *et al.* (2001). The other possible reason for increased nitrogen uptake may be N-fixation by legumes and biofertilizrer (*Azotobacter* and *Azospirillum*). The activity of these microorganisms might have improved in the presence of adequate supply of organic matter. Nitrogen uptake by wheat was high when preceded by leguminous pulse crops in the cropping sequence. This may be attributed to the residual effect of leguminous crops which might have resulted into better crop growth and development in succeeding wheat crop and consequently higher nitrogen uptake.

Effect on soil fertility

After 2 years of field experimentation, combined application of chemical, biological and organic sources of nutrients resulted in significantly higher nitrogen, phosphorous and potassium status in the soil. This treatment resulted in 12.3, 21.2 and 11.3% increase in available nitrogen, available phosphorous and available potassium over the alone application of chemical fertilizers. The results are in line with the findings of Sharma *et al.* (2001). Nitrogen status in the soil was significantly lower with cereal–cereal sequences in comparison to the wheat-pulse sequences, highest value recorded for wheat-soybean sequence (275.1kg/ha), which was 10.7, 15.5 and 13.5% higher than recorded for wheat-rice, wheat-maize and wheat-sunflower sequences, respectively. These results indicate that inclusion of leguminous crop in the system have definite positive effect on nitrogen status in soil. No significant variation was found in phosphorous status of soil excluding wheat-sunflower sequence. This may be attributed to the application of comparatively higher doses of phosphorus to sunflower resulting in greater residual phosphorus in soil. Available potassium in the soil was significantly higher in wheat-soybean, followed by wheat–Frenchbean sequence compared with cereal-cereal sequences. This may be attributed to the exhaustive nature of cereals.

Effect on kharif crops and system productivity

Significant variation was not noticed between the wheat equivalent yields of different *kharif* crops with an exception of sunflower, which failed to produce wheat equivalent yield comparable with other crops. This may be due to lower production per unit area and comparatively less market prices due to lack of oil extraction in the valley. The higher values were recorded for rice and soybean crops. Wheat–rice sequence registered significantly higher wheat equivalent yield compared to wheat-maize and wheat-sunflower. This was attributed to higher equivalent yield in rice which compensated slight decline in yield of succeeding wheat. Other cropping sequences were at par except wheat–sunflower sequence which recorded signifi-

Table 3. Yield attributes and grain yield of wheat as influenced by fertilizer management and residual effect of preceding crop.

Treatment	Ears/m^2		Grains/ear		Ear weight (g)		Grain yield (t/ha)		Straw yield (t/ha)	
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
Fertility level										
RDF	308	325	38.4	38.2	2.34	2.37	4.56	4.65	7.52	7.54
RDF + 15 t FYM	355	356	40.4	40.1	2.44	2.51	5.19	5.58	8.18	8.58
RDF + Bio-fertilizers	315	331	38.6	39.9	2.36	2.38	4.62	4.77	7.61	7.57
RDF + 15 t FYM + Bio-fertilizers	363	366	41.5	41.7	2.53	2.57	5.36	5.72	8.33	8.60
SEm±	3.5	2.5	0.2	0.3	0.01	0.01	0.36	0.40	0.30	0.42
CD (P=0.05)	12.2	8.7	0.7	0.9	0.04	0.02	1.27	1.38	1.03	1.46
Cropping sequence										
Wheat–rice	336	353	39.8	39.3	2.43	2.49	4.95	5.22	7.89	8.08
Wheat–maize	334	307	39.7	38.6	2.42	2.41	4.91	4.85	7.90	7.76
Wheat–sunflower	333	343	39.3	39.6	2.40	2.42	4.93	5.18	8.01	8.16
Wheat–greengram	335	375	39.9	41.0	2.42	2.51	4.91	5.43	8.00	8.29
Wheat–Frenchbean	337	312	39.7	39.3	2.41	2.41	4.92	4.93	7.88	7.87
Wheat–soybean	335	376	39.8	40.7	2.41	2.52	4.95	5.43	7.85	8.33
SEm±	3.6	4.35	0.70	0.74	0.01	0.01	0.76	0.81	0.51	0.65
CD (P=0.05)	NS	12.48	NS	2.12	NS	0.04	NS	2.79	NS	1.86

Table 4. Productivity, nitrogen uptake, profitability and soil fertility as influenced by fertilizer management and cropping systems

Treatment	Wheat equivalent yield (t/ha)			Nitrogen uptake (kg/ha)		Net returns	B:C ratio	Available NPK (kg/ha)		
	Rabi	*Kharif*	sequence	2005	2006	(×10^3 ₹/ha)		N	P	K
Fertility level										
RDF	4.6	4.3	9.0	106.9	112.4	48.7	1.62	241.	21	209
RDF + 15 t FYM	5.4	4.7	10.1	114.2	118.3	53.3	1.44	287	22	224
RDF + Bio-fertilizers	4.7	4.6	9.3	110.2	114.1	50.4	1.67	243	23.	214
RDF + 15 t FYM + Bio-fertilizers	5.5	5.0	10.5	124.6	127.0	57.1	1.53	271	25	232
SEm±	0.2	0.14	0.15	1.03	0.89	-	-	2.7	0.5	3.7
CD (P=0.05)	0.7	0.49	0.50	3.54	3.08	-	-	8.4	1.6	12.7
Cropping sequence										
Wheat-rice	5.1	5.0	10.1	114.1	117.80	57.7	1.55	248.	22.	215
Wheat-maize	4.9	4.7	9.6	113.3	109.71	56.7	1.72	238	22	207
Wheat-sunflower	5.0	3.5	8.5	114.4	118.14	41.5	1.25	242	25	223
Wheat-greengram	5.2	4.8	10.0	114.5	125.72	54.6	1.71	270	22	219
Wheat-Frenchbean	4.9	5.1	10.0	113.8	113.21	50.4	1.36	275	23	220
Wheat-soybean	5.2	4.8	10.0	113.6	123.24	53.8	1.70	260	22	225
SEm±	0.06	0.10	0.15	2.22	1.68	-	-	3.8	0.5	2.9
CD (P=0.05)	0.20	0.35	0.43	NS	5.3	-	-	12.9	1.3	9.4

cantly lower equivalent yield in comparison to rest of sequences. Lower productivity in wheat–sunflower sequence may be attributed to lower production potential and exhaustive nature of the sunflower. In wheat–maize sequence, the lower productivity was attributes to the depressed yield of wheat due to delayed sowing of wheat and exhaustive nature of maize crop. These results are in conformity with the findings of Bhagat and Dhar (2003).

Economics

Net returns were higher with combined application of RDF + FYM + biofertilizer (Table 4), followed by RDF + FYM. Ram and Mir (2006) also reported maximum net returns from farmyard manure 15 tonnes/ha + nitrogen 100 kg/ha + biofertilizer (*Azotobacter* + *Azospirillum*). Higher B:C ratio (1.67) was recorded for the combined application of recommended fertilizer dose + biofertilizer. Wheat–rice sequence recorded highest net returns (₹57,627/ha). This might be due to higher production potential of this sequence in comparison to others. Wheat-maize sequence recorded maximum values for B:C ratio (1.82). Wheat–sunflower sequence with net profit of ₹41,521/ha proved least profitable in comparison to other cropping sequences.

It was concluded that combined application of inorganic, organic and biological sources of nutrients to wheat crop significantly improved productivity and monetary returns. Wheat–rice sequence proved more productive and remunerative and could be recommended for maximum profit under temperate Kashmir conditions. Wheat–pulse sequences produced beneficial residual effect on succeeding wheat and soil fertility.

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