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Research Paper

Fertilizer schedule under limited irrigation with zero-tilled wheat (*Triticum aestivum*) after rice (*Oryza sativa*) in north-west Himalayas

S.C. NEGI[1], J. SHEKHAR[2], B.S. MANKOTIA[3] AND GURUDEV SINGH[4]

CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh 176 062

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ABSTRACT

Field experiment was conducted for two years during 2005-06 and 2006-07 at CSKHPKV, Rice and Wheat Research Centre, Malan to find out the fertilizer schedule for limited irrigation zero-tilled wheat {*Triticum aestivum* (L.) emend. Fiori & Paol.}. Five nitrogen levels *viz.,* 0, 60, 90, 120 and 150 kg/ha along with 40 kg P_2O_5 and 40 kg K_2O/ha in main plots and three time-methods of fertilizer application *viz.* M_1: Placement of $^1/_3$ N with full P and K as basal & topdressing $^2/_3$ N at first node stage, M_2: Broadcast of $^1/_3$ N with full P and K as basal & topdressing $^2/_3$ N at first node stage, and M_3: Broadcast of full P and K as basal & full N one month after sowing, in sub-plots were tested using split plot design replicated thrice. Significant response of wheat to nitrogen application was observed up to 150 kg N/ha, which was more profitable too. Grain and straw yield of the crop was significantly higher at 150 kg N/ha compared to lower levels. Increase was 30.6 (0.75 t/ha) and 27.0 (0.59 t/ha) per cent over the 90 kg N/ha in first and second year, respectively. Mean net returns were ₹33,950/ha and benefit : cost ratio 2.45 were the highest at 150 kg N/ha. N use efficiency was 11.0 & 13.2 kg grain/kg N applied at this level in 2005-06 and 2006-07, respectively. The relationship between grain yield and N was quadratic in nature predicting still higher dose of optimum N. Wheat grain yield was significantly varied by time and method of fertilization application. In 2005-06 which was a drought like year at initial phase, application of full dose of N one month after sowing (M_3) recorded significantly higher grain yield (2.69 t/ha) compared to $^1/_3$ N applied at sowing time and $^2/_3$ N at first node in M_1 and M_2 treatments. Whereas in 2006-07 rainfall was comparatively well distributed and application of $^1/_3$ N with full P and K as basal placement (M_1) recorded significantly higher values of grain yield and straw yield compared to M_2 and M_3 treatments. Similarly M_3 was more economical (net returns ₹30,307/ha, 2.32 B:C) in drought like year and M_1 in 2006-07. Thus, placement of 50 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha as basal dose followed by topdressing of 100 kg N/ha at first node stage be adopted to realize more productivity of zero-tilled wheat under limited irrigation conditions in north western Himalayas. However, if there is dry spell during the initial crop phase, Broadcast of full P & K as basal and full N one month of sowing is also effective.

Key words: Limited Irrigation, N response, Time and method of fertilizer application, Wheat, Zero-tillage

Rice–wheat is the most predominant cropping system in India, occupying more than 10 m ha area especially in North India. Likewise, wheat is also one of most important cereal crops of Himachal Pradesh covering an area of 362.2 thousand hectares. Since, 80% of wheat is cultivated under rainfed conditions, its productivity in the state is low at 1646 kg/ha. Due to inadequate rains at the start of winters, the farmers are not able to sow wheat well in time since paddy matures late sometimes in November also. Therefore, farmers are left with no option but to go in for late sowing of wheat. Zero tillage cultivation of wheat has many advantages (Jat *et al*, 2009, Raj Gupta *et al*, 2010), the main advantage being it advances the wheat sowing by 4-5 days as no extra time is required for field preparation. Additionally it saves 92 per cent diesel compared to conventional system, requires less water for irrigation and reduced infestation of *Phalaris minor* which is the main problem in North India. Besides, it ensures eco-friendly wheat cultivation by reducing 135 kg CO_2/ha (assuming 2.6 kg CO_2 per liter of diesel burnt) which is one of the major causes of global warming. In rice-wheat system, the nitrogen management may differ because rice stubbles cause higher nitrate depression for initial 4-6 weeks under zero tillage which may result in immobilization of nitrogen. Keeping this in view, present investigation was undertaken to find out the response to different levels of nitrogen as well as time and method of fertilizer application to zero-tilled limited irrigation wheat under mid hill condi-

[1]**Corresponding author Email:** drscnegi@yahoo.in

[1]Chief Scientist, [2]Senior Scientist, Deptt of Agronomy; [3]Scientist, KVK Kukumseri (L&S), [4]Assistant Scientist, HAREC-Bajaura, Kullu, H.P.

tions of Himachal Pradesh.

MATERIALS AND METHODS

Field experiment was conducted for two years during 2005-06 and 2006-07 to find out the response to nitrogen application by zero-tilled limited irrigation wheat as well as time and method of fertilizer application at CSK Himachal Pradesh Krishi Vishvavidyalaya, Rice and Wheat Research Centre, Malan (32°1'E, 76°2'N & 950 m above mean sea level, average annual rainfall 1800 mm). The soil of the experimental site was silty clay loam in texture, acidic in reaction (pH 5.8), medium in available nitrogen (362 kg/ha), phosphorus (18 kg/ha) and potassium (132 kg/ha).

The treatments consisted of five levels of nitrogen viz. 0, 60, 90,120 and 150 kg/ha along with 40 kg P_2O_5 and 40 kg K_2O/ha (uniform application) in main plots and three treatments involving methods and time of fertilizer application viz. M_1 : Placement of $^1/_3$ N with full P and K as basal & topdressing $^2/_3$ N at first node stage, M_2 : Broadcast of $^1/_3$ N with full P and K as basal & topdressing $^2/_3$ N at first node stage and M_3: Broadcast of full P and K as basal and full N one month after sowing in sub plots of split plot design replicated thrice.

Wheat 'Aradhana' was sown in 1st week of December in both years using 100 kg seed/ha after harvest of rice which received 90, 40, 40 kg N, P_2O_5, K_2O/ha. No application of paraquat was made as the field was free of weeds. The major weed flora infesting the experimental field during the crop seasons comprised of *Medicago denticulata*, *Stellaria media*, *Lathyrus aphaca*, *Fumaria parviflora*, *Phalaris minor*, *Lolium temulentum*, *Poa annua* etc, and was controlled effectively by post emergence tank mix application of Isoproturon @ 1.0 kg/ha + 0.5 kg 2,4-D/ha. During 2005-06, it rained 175.4 mm in 23 rainy days (no rainfall from October to December, 66.3 mm in January, 7.2 mm in February, 88.8 mm in March & 13.1 mm in April), whereas during 2006-07, 358.4 mm rainfall with reasonable distribution was received (14.3 mm in October, 7.8 mm in November, 42.1 mm in December, 0.0 rainfall in January, 132.4 mm in February, 159.5 mm in March and 2.3 mm in April). Economics was computed using prevailing costs of inputs and labour and returns were computed by grain price as ₹ 12,000/t and straw price as ₹3,000/t. In hills, the straw is also an important economical part as the same is fed to the cattle as the animal husbandry is an integral part of hill farming.

RESULTS AND DISCUSSION

Effect of nitrogen levels

Significant effect of different levels of nitrogen was observed on test weight, straw yield, grain yield and N-use efficiency (Table 1 & 2) whereas initial plant stand and the grains per spike remained unaffected hence data are not given. Nitrogen application improved the values of test weight over the control (no N application) during both the years. Application of 150 kg N/ha recorded significantly higher test weight over control but was at par with other lower levels of nitrogen. This might be due to increased cell division and cell expansion with the increased N availability.

In general, the crop productivity was comparatively less in the second year of experimentation because of the low minimum & maximum temperature prevailing in the month of January, February and March in 2nd year compared to 1st year of experimentation. The Low temperature might have affected initial growth of the crop, thereby resulting in reduced grain yields in 2006-07. Also the water availability for initial irrigation was not available in 2nd year because of scarcity of water in *Kuhl* irrigation. Significant improvement in both grain and straw yields was recorded with nitrogen application during both the years. Grain and straw yield of the crop was significantly higher at 150 kg N/ha compared to other N levels. On an average, the increase was 30.6 (0.75t/ha) and 27.0 (0.59 t/ha) per cent over the 90 kg N/ha. The results confirm the findings of Kumar and Yadav (2005) and Yadav *et al*. (2005) who also reported significant increase in grain yield of zero-tilled wheat upto 150 kg N/ha. Peoples & Herridge (1990) and Rao and Dao (1992) suggested that cereals under reduced and no tillage may require additional nitrogen to reach production level similar to those of conventional tillage because of the low extraction efficiency of soil available nitrogen. The relationship between seed yield of wheat and nitrogen was quadratic in nature (Table 4) during both the years as well as for the average yield. Based on the average of two years, productivity level of 3.43t/ha was estimated at optimum level of N (276 kg/ha).Thus, revealing that higher level of nitrogen is required under zero tilled wheat.

N-use efficiency (kg grain produced/kg of N applied) was significantly varied with variation in level of N applied. Application of 60 kg N/ha recorded significantly higher efficiency value (17.9 and 15.1 kg/kg N) over 120 kg N/ha during both the years as well as over 150 kg N/ha (11.0 kg/kg N) during 2005-06.

Effect of time and method of fertilizer application

Initial plant stand were similar during both the years due to different time and method of fertilizer application indicating that nutrients from seed and soil were sufficient for the crop establishment. Hence, data not reported. Significant variation in test weight, grain yield, straw yield and N-use efficiency was recorded during both the years.

In 2005-06 which was a drought like year, application of full dose of N one month after application (M_3) recorded significantly higher grain yield (2.69 t/ha) compared to $^1/_3$ N applied at sowing time and $^2/_3$ N at first node in M_1 and M_2 treatments. Straw yield in M_3 was significantly more compared to M_2 whereas test weight was statistically similar in both the treatments. Comparison of M_1 and M_2 reveals that former recorded significantly more grain yield by 0.13t/ha. Straw yield and test weight were also significantly more in M_1 compared to M_2. Better performance of M_1 is ascribed to the placement of the major nutrients which might have increased their availability to the roots of crop, compared to the broadcast in M_2 where major portion of nutrients particularly phosphorus might have remained on the surface of soil. N use efficiency (14.6 kg grain/kg N) was significantly more in M_3 followed by M_1 (11.6 kg grain/kg N) and M_2.

In 2006-07 rainfall was comparatively well distributed (Table 1). Application of $^1/_3$ N with full P and K as basal placement (M_1) recorded significantly higher values of grain yield and straw yield compared to M_2 in which these nutrients were applied as broadcast. Broadcast might have reduced the availability of these major nutrients particularly of phosphorus as most of it might have remained on the surface of soil. In M_3, the crop might have suffered for a month for want of nitrogen; therefore, it recorded significantly less grain and straw yield compared to M_1 and M_2 where $^1/_3$ N was basally placed/broadcast. Comparison of M_3 and M_2 reveals that grain and straw yields were significantly less in M_3 where crop suffered for want of N for a month. Thereby revealing that in a good rainfall year, basal application of N is must for zero tilled wheat otherwise it reduces the productivity. N-use efficiency (kg grain/kg N) followed the trend of wheat productivity and differed significantly from one another. Thus, basal placement (M_1; 18.5 kg grain/kg N) & broadcast (M_2; 13.0 kg/kg N) recorded significantly more efficiency value compared to M_3 (9.7 kg/kg N).

Table 1. Climatic parameters during the experimental period

Month	2005-06				2006-07			
	Rainfall (mm)	Rainy days	Max. Temperature (^oC)	Min. Temperature (^oC)	Rainfall (mm)	Rainy days	Max. Temperature (^oC)	Min. Temperature (^oC)
October	0.0	0	26.9	14.7	14.3	2	27.7	14.8
November	0.0	0	23.2	9.3	7.8	1	23.1	10.5
December	0.0	0	18.8	5.4	42.1	4	20	6.9
January	66.3	6	17.2	5.1	0.0	0	18.4	4.4
February	7.2	2	23.8	9.1	132.4	7	18.4	6.9
March	88.8	8	23.4	9.4	159.5	8	22.7	8.1
April	13.1	3	29.6	12.7	2.3	1	30.2	15.2
Total	175.4	19	-	-	358.4	23	-	-

Table 2. Effects of fertilizer scheduling on test weight, straw yield and N-use efficiency in wheat

Treatment	1,000-grain weight (g)		Straw yield(t/ha)		N use efficiency(kg grain/kg N applied)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
N (kg/ha)						
0	41.6	44.4	1.949	1.275		
60	44.7	48.4	3.550	2.289	17.9	15.1
90	45.6	47.3	3.458	2.776	10.1	15.4
120	45.6	47.2	3.850	2.765	9.6	11.4
150	46.4	48.9	4.414	3.635	11.0	13.2
SEm±	1.05	0.78	0.14	0.18	0.66	1.11
CD (P=0.05)	3.1	2.3	0.401	0.531	1.94	3.27
Fertilizer scheduling						
M_1 : $^1/_3$ N placed* & $^2/_3$ N topdressing at first node stage	46.9	48.0	3.535	2.967	11.6	18.5
M_2 : $^1/_3$ N broadcast* & topdressing $^2/_3$ N at first node stage	43.8	47.5	3.197	2.603	10.1	13.0
M_3 : 100% N broadcast one month after sowing*	43.7	46.2	3.690	2.073	14.6	9.7
SEm±	0.57	0.43	0.06	0.07	0.26	0.48
CD (P=0.05)	1.87	NS	0.204	0.245	0.84	1.58

*Full P & K was applied as basal placement in M_1 and as broadcast in M_2 & M_3

Interaction effect

Significant interaction effect of nitrogen levels and time-method of fertilizer application was observed on wheat productivity during both the years (Table 3). In drought like year 2005-06, nitrogen level of 150 kg/ha applied as M_3 (broadcast N one month after sowing) recorded significantly highest wheat productivity (3.39 t/ha) compared to all other combinations except at the same nitrogen level applied as M_1 (placement of $^1/_3$ N with full P and K as basal & topdressing $^2/_3$ N at first node stage). Notably, at lower N levels upto 60 kg/ha, the wheat productivity under M_3 was significantly highest compared to M_1 and M_2, whereas at 90 kg and above N levels it was highest under M_3 but statistically at par with M_1. During the normal rainfall year 2006-07, while all the time-methods of nutrient application were at par in the absence of

Table 3. Interaction effect of nitrogen levels and time-method of fertilizer application on the grain yield (t/ha) of zero tilled wheat

N (kg/ha)	M_1 : $^1/_3$ N placed* & $^2/_3$ N topdressing at first node stage		M_2 : $^1/_3$ N broadcast* & topdressing $^2/_3$ N at first node stage		M_3 : 100% N broadcast one month after sowing*		Mean	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
0	1.367	0.741	1.427	0.806	1.746	0.849	1.530	0.798
60	2.500	2.048	2.509	1.721	2.740	1.352	2.606	1.706
90	2.590	2.560	2.220	2.135	2.500	1.852	2.435	2.182
120	2.900	2.876	2.440	1.961	3.090	1.655	2.673	2.164
150	3.260	3.398	2.890	2.745	3.390	2.178	3.181	2.774
Mean	2.441	2.324	2.313	1.873	2.692	1.577		
SEm±							0.07	0.13

CD (P=0.05)	*2005-06*	*2006-07*
N levels (N)	0.221	0.372
Fertilizer schedule (FS)	0.095	0.180
FS at same N	0.212	0.402
N at same or different FS	0.298	0.390

*Full P & K was applied as basal placement in M_1 and as broadcast in M_2 & M_3

Table 4. Response functions and wheat productivity at optimum N level

Response function	R^2	Optimum N(kg/ha)	Yield at optimum N level (t/ha)
		2005-06	
$Y=1599+13.4N-0.025N^2$	0.87	238	3.38
		2006-07	
$Y=817+15.8N-0.0223N^2$	0.95	319	3.57
		Average (2005-06 and 2006-07)	
$Y=1599+13.4N-0.025N^2$	0.94	276	3.43

Table 5. Gross & net returns (/ha) and benefit: cost ratio under different treatments ₹

Treatment	Gross returns (× 10^3 ₹/ha)		Net returns (× 10^3 ₹/ha)		B:C ratio	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
N (kg/ha)						
0	24.2	13.4	12.2	1.401	1.02	0.12
60	41.9	27.3	29.1	14.525	2.27	1.13
90	39.6	34.5	26.4	21.352	2.01	1.62
120	43.6	34.3	30.1	20.757	2.23	1.54
150	51.4	44.2	37.6	30.340	2.71	2.19
Fertilizer scheduling						
M_1 : $^1/_3$ N placed* & $^2/_3$ N topdressing at first node stage	39.9	36.8	26.8	23.7	2.05	1.82
M_2 : $^1/_3$ N broadcast* & topdressing $^2/_3$ N at first node stage	37.3	30.3	24.3	17.2	1.86	1.32
M_3 : 100% N broadcast one month after sowing*	43.4	25.1	30.3	12.1	2.32	0.92

*Full P & K was applied as basal placement in M_1 and broadcast in M_2 & M_3

nitrogen application (zero N level), M_1 was significantly superior to the other two methods (M_2 and M_3) for all the other N levels (60-150 kg N/ha) tried in the experiment.

Economics

In agreement with grain and straw yields the gross and net returns as well as benefit: cost ratio were highest at 150 kg N/ha (Table 5). Thus, this N level recorded highest net returns of ₹ 33,950/ha with benefit: cost ratio of 2.45. The values were lowest (₹6,804/ha & 0.57) when no nitrogen was applied. Placement of fertilizers (M_1) was more economical with higher gross and net returns as well with higher benefit: cost ratio, rather than their broadcast application at sowing (M_2) during both the years and as well to the broadcast of full N one month after sowing (M_3) during 2006-07. On an average M_1 recorded ₹ 4,527/ha more net returns over M_2. However in 2005-06, broadcast of full N one month after sowing was more economical. This trend in economic returns is mainly due to the treatment effects on the grain and straw yields.

Thus, it is concluded that for higher productivity of zero-tilled wheat in north- west Himalayas, a fertilizer dose of 150 kg N and 40 kg each of P_2O_5 and K_2O be applied as 1/3 N and full P and K as placement at sowing and remaining 2/3 N topdessed at first node stage. In case of dry spell during the initial crop phase, Broadcast of P and K at sowing and full N one month after sowing is also equally effective.

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