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Impact of Nutrient Management Practices on Yield, Quality and N Uptake in Wheat-pulse Intercropping under the North Western Himalayan Region

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Abstract

The experiment comprising of three nutrient management practices viz., Recommended Nutrient Management (RNM), Organic Nutrient Management (ONM) and Natural Nutrient Management (NNM) as main-plots and five wheat-based intercropping systems [Wheat (sole), W; Wheat + chickpea (2:1), W + C (2:1); Wheat + chickpea (2:2), W + C (2:2); Wheat + lentil (2:1), W + L (2:1); and Wheat + lentil (2:2), W + L (2:2)] as sub-plots was conducted under a split-plot design with three replication during Rabi season of 2023-24 and 2024-25 at Palampur. Among nutrient management practices, RNM practices were more promising for most of the traits than NNM. RNM practices resulted in higher grain and straw yield, Wheat Equivalent Yield (WEY), nitrogen content in grain and straw of wheat and combined nitrogen uptake (wheat + intercrop) by grain and straw. Significantly higher WEY and N uptake were found in the W + C (2:1) intercropping system.

Keywords: Equivalent Yield, Intercropping, Natural Farming, Organic Farming, Wheat

The North-Western Himalayan region, particularly the mid-hills of Himachal Pradesh, represents a unique agro-ecological niche where agriculture is the primary livelihood for the majority of the rural population. Wheat (*Triticum aestivum* L.) stands as the foundational cereal crop of this region, yet its productivity is increasingly challenged by the inherent limitations of acid Alfisols. These soils are characterised by an acidic pH, which significantly restricts the availability of essential nutrients, particularly phosphorus, through high fixation rates. For decades, the reliance on RNM, as characterised by heavy applications of synthetic fertilisers, has been the standard strategy to overcome these limitations[1]. However, there is growing evidence that long-term dependence on chemical-intensive monocultures has led to the degradation of soil biological integrity and a decline in nutrient-use efficiency[2].

In response to these sustainability challenges, there is a paradigm shift toward "Rhizosphere Engineering" through cereal-legume intercropping and the adoption of alternative production systems. Natural Farming (NF) and ONM models have emerged as promising pathways to rejuvenate soil health. Natural farming,

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in particular, utilises fermented microbial inputs like *Jeevamrit* and *Ghanjeevamrit* to stimulate the soil's indigenous microflora, thereby improving the nutrient-supplying capacity of the rhizosphere through biological facilitation[3-5]. Unlike conventional systems that focus on direct nutrient supply to the plant, these sustainable models aim to enhance the soil's biological fertility to drive crop growth.

The integration of pulses, such as chickpea (*Cicer arietinum* L.) and lentil (*Lens culinaris* Medikus), into wheat-based systems offers a biological tool to further optimise nutrient dynamics. Legumes are well-known for their ability to fix atmospheric nitrogen and release organic acids in the rhizosphere, which can solubilise fixed phosphorus in acidic soils. When grown in association with wheat, these pulses introduce a level of temporal and spatial complementarity that can enhance the total system productivity and nutrient harvest index. Integration of pulses as an intercrop enhances yield and quality of the main crop[6]. However, the performance of these intercropping systems varies significantly depending on the row ratios (such as 2:1 or 2:2) and the nutrient management strategies applied.

Despite the regional push for natural and organic farming in Himachal Pradesh, there is a critical need for comprehensive research that decouples the impacts of these management regimes on the nitrogen content and total uptake in diversified systems. Most existing studies focus primarily on yield, often overlooking the complex partitioning of nitrogen between the grain and straw of both the main crop and the intercrop. Understanding these dynamics is essential to determine whether sustainable management can truly provide a viable economic and biological alternative to chemical-based packages. Therefore, the present investigation was conducted at CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, to assess the impact of natural, organic and recommended management on the yield dynamics and nitrogen uptake of wheat-pulse intercropping systems in the sub-temperate North-Western Himalayas.

MATERIALS AND METHODS

The experiment was conducted at Integrated Research Farm, Department of Organic Agriculture & Natural Farming of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The experimental farm is located at 32°06′10′′ N latitude, 76°33′40′′E longitude, perched in the lap of the majestic snow-clad Dhauladhar range of North Western Himalayas at an elevation of 1290.8 meters above mean sea level. The field was located in the Palam Valley of Kangra district under the mid-hills sub-humid agro-climatic zone of Himachal Pradesh, India. The soil of the experimental field was silty-clay loam in texture and acidic in reaction (5.21), medium in organic carbon (8.32 g/kg) and low in available nitrogen (247 kg/ha) and medium in available phosphorus (15.7 kg/ha) and potassium (241 kg/ha). Total amount of rainfall received was 352.8 and 397.3 mm during 2023-24 and 2024-25. The fifteen treatment combinations comprising of three nutrient management practices, *viz.,* recommended nutrient management, organic nutrient management and natural nutrient management, and five wheat-based intercropping systems, *viz.,* wheat (sole), wheat + chickpea (2:1), wheat + chickpea (2:2), wheat + lentil (2:1) and wheat + lentil (2:2) were tested, where, nutrient management practices were allocated in the main plots and intercropping systems were allocated in the sub-plots. The wheat, chickpea and lentil crops with different nutrient management practices were raised in accordance with the recommended package of practices for *Rabi* crops[7]. As per the treatments, *Ghanjeevamrit* at the rate of 500 kg/ha, a solid organic inoculation, was applied on a dry weight basis at the time of sowing. These materials were uniformly spread over the soil surface and subsequently incorporated into the soil in the natural farming plots. Whereas in organic farming plots, vermicompost was applied uniformly over the soil surface at the time of sowing (5 t/ha). In the case of RNM practices, the wheat crop was fertilised with 120: 60: 30 kg NPK/ha, and the sources used included urea (46% N) and IFFCO (12: 32: 16). Prior to sowing, seeds of wheat, chickpea and lentil were treated with *Beejamrit* at the rate of 100 ml per kg under natural farming treatments. Whereas in the case

of organic farming treatments, seeds of wheat, chickpea and lentil were treated with different biofertilizers; chickpea and lentil were inoculated with *Rhizobium* + PSB culture and those of wheat with *Azotobacter* + PSB. The sowing of variety "HPW 368" (wheat), "*Him Palam Chana* 1" (chickpea) and "*Markandey*" (lentil) was done in well prepared seed bed at a spacing of 22 cm row to row at the rate of 100 kg/ha (wheat), 45 kg/ha (chickpea) and 30 kg/ha (lentil) in the different nutrient management practices. The intercropping treatments were established using replacement series. In these treatments, the wheat rows were replaced with the intercrop, *i.e.*, *viz.*, chickpea and lentil. *Setaria* grass was used as surface mulch to facilitate soil moisture conservation and suppress weed growth, ensuring an optimal hydrothermal environment for the wheat-based systems.

After harvesting the net plot area, produce was then threshed manually, winnowed, and grains were cleaned and separated out. The weight of the grains was recorded on an electronic balance and converted into kilograms per hectare (kg/ha). The wheat equivalent yield of intercrop (gram or lentil) was computed by multiplying the intercrop yield by the wheat equivalent factor and added to wheat yield to get the total wheat equivalent yield. The grain yield so recorded from each net plot was subtracted from the biological yield of each net plot to get the straw yield. This straw yield per net plot was then converted to kilograms per hectare (kg/ha). The samples of grain and straw from each plot were collected and subjected to chemical analysis to determine the per cent nitrogen content in grain and straw[8]. Total uptake of N by grain and straw was calculated by multiplying the percentage of nitrogen in grain by total grain yield (kg/ha) and the percentage of each nutrient in straw-by-straw yield (kg/ha), and the total amount of nutrient uptake by the crop at the time of maturity was estimated by summing up both. Nutrient uptake was calculated with the help of formula given[9]:

$$\text{WEY} = \frac{\text{wheat yield} + \text{IC yield} \times \text{IC Price}}{\text{Price of wheat crop}}$$

IC = intercropping

Yield and price in kg/ha and (₹/kg), respectively

Total uptake = Uptake by grain + Uptake by straw

The data were subjected to statistical analysis following Gomez and Gomez[10], and the Critical Differences (CD) were assessed at <0.05.

RESULTS AND DISCUSSION

A critical examination of the data on the effect of different nutrient management practices and wheat-based intercropping systems on yield (Table 1) revealed that higher grain and straw yield were recorded under RNM, whereas the lowest grain yield was obtained under NNM. WEY was significantly influenced by different nutrient management practices and wheat-based intercropping systems during both years. Significantly higher WEY was recorded under RNM practices, which was 30.7 and 28.0 per cent higher than ONM practices during the first and second years, respectively. These results are in conformity with the findings of Praharaj *et al.*[11] and Behera and Chandrashekara[12], who also found that the recommended package of practices consistently out-yielded organic and natural farming systems in wheat-based rotations. W + C (2:1) had higher WEY among the different wheat-based intercropping systems, which was statistically at par with W + C (2:2). The lowest WEY was recorded in W + L (2:2). Singh and Yadav also reported that the W + C intercropping system resulted in higher wheat yield over W + L. These findings are supported by Anshumali[13] and Raveena[14], who noted that chickpea-based intercropping in a 2:1 offers the highest system productivity under the mid-hill conditions of Himachal Pradesh.

Nitrogen content in grain and straw along with protein content was significantly influenced by different nutrient management practices during both years (Table 2). Significantly higher N and protein content was found under RNM practices. NNM practices had the lowest nitrogen and protein content. The nitrogen content in grain and straw under RNM practices was 3.4 and 2.2 per cent in 2023-24 and 6.7 and 5.8 per cent in 2024-25, respectively, higher than under ONM

Table 1. Effect of nutrient management practices and wheat-based intercropping systems on grain, straw and wheat equivalent yield (kg/ha)

	Grain yield				Straw yield				Wheat equivalent yield	
	Wheat		Intercrop		Wheat		Intercrop			
Treatment	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
Nutrient management practices										
Recommended nutrient management	2435	2523	445	476	3641	3781	640	649	3586	3726
Organic nutrient management	1798	1901	353	386	2668	2781	506	516	2744	2911
Natural nutrient management	1515	1647	325	353	2216	2369	467	476	2391	2576
SEm±									54	62
LSD (P=0.05)									212	242
Wheat-based intercropping systems										
Wheat	2787	2944	0	0	4087	4313	0	0	2870	2944
Wheat + Chickpea (2:1)	2057	2172	429	465	3049	3192	601	611	3110	3283
Wheat + Chickpea (2:2)	1493	1577	608	658	2224	2324	855	869	2983	3148
Wheat + Lentil (2:1)	1858	1962	352	681	2763	2881	523	532	2879	3043
Wheat + Lentil (2:2)	1386	1464	481	520	2085	2174	710	723	2777	2935
SEm±									51	53
LSD (P=0.05)									148	155

practices. Nitrogen and protein content remained unaffected due to wheat-based intercropping systems.

A perusal of data on the effect of different nutrient management practices and wheat-based intercropping systems on nitrogen uptake by grain/seed and straw as well as total uptake (Table 3) indicated that nitrogen uptake by grain, straw and total was significantly influenced by different nutrient management practices and wheat-based intercropping systems during 2023-24 and 2024-25. Significantly higher N uptake was recorded under RNM practices. N uptake under RNM practices by grain, straw and total was 35.5, 33.6 and 39.2 per cent in 2023-24 and 35.2, 36.5 and 38.6 per cent during 2024-25 over ONM practices, respectively. Similarly, Tigangam *et al.*[15] reported that inorganic sources generally result in higher nitrogen content in wheat tissues compared to biological sources in the early years. W + C (2:1) recorded significantly higher values of N content, protein content and N uptake by grain, straw and total during both the years. The higher nitrogen content in the 2:1 chickpea-based system is likely due to the legume effect, where the nitrogen fixed by chickpea nodules was shared with the neighbouring rows of wheat through the rhizosphere. Chickpea is

Table 2. Effect of nutrient management practices and wheat-based intercropping systems on nitrogen and crude protein content (%) in wheat

	Nitrogen content				Crude protein content	
	Grain		Straw			
Treatment	**2023-24**	**2024-25**	**2023-24**	**2024-25**	**2023-24**	**2024-25**
Nutrient management practices						
Recommended nutrient management	1.54	1.60	0.474	0.437	9.00	9.34
Organic nutrient management	1.49	1.50	0.464	0.413	8.67	8.74
Natural nutrient management	1.44	1.40	0.414	0.389	8.41	8.16
SEm±	0.01	0.02	0.006	0.004	0.07	0.12
LSD (P=0.05)	0.05	0.08	0.021	0.016	0.29	0.46
Wheat-based intercropping systems						
Wheat	1.48	1.48	0.443	0.407	8.65	8.61
Wheat + Chickpea (2:1)	1.51	1.58	0.460	0.439	8.80	9.21
Wheat + Chickpea (2:2)	1.50	1.52	0.460	0.417	8.77	8.86
Wheat + Lentil (2:1)	1.49	1.49	0.450	0.410	8.67	8.68
Wheat + Lentil (2:2)	1.47	1.44	0.440	0.391	8.57	8.37
SEm±	0.04	0.03	0.008	0.010	0.23	0.18
LSD (P=0.05)	NS	0.09	NS	0.028	NS	0.54

Table 3. Effect of nutrient management practices and wheat-based intercropping systems on nitrogen uptake (kg/ha)

	Nitrogen uptake					
	Grain		Straw		Total	
Treatment	**2023-24**	**2024-25**	**2023-24**	**2024-25**	**2023-24**	**2024-25**
Nutrient management practices						
Recommended nutrient management	51.16	55.18	22.19	21.65	73.35	76.84
Organic nutrient management	37.76	40.82	16.61	15.86	54.38	56.67
Natural nutrient management	31.84	34.26	12.74	12.90	44.57	47.16
SEm±	0.59	0.49	0.20	0.52	0.76	0.98
LSD (P=0.05)	2.30	1.90	0.78	2.02	2.97	3.83
Wheat-based intercropping systems						
Wheat	41.63	44.03	18.35	17.77	59.98	61.80
Wheat + Chickpea (2:1)	44.30	48.82	18.85	18.94	63.15	67.76
Wheat + Chickpea (2:2)	41.38	44.65	17.25	16.90	58.63	61.55
Wheat + Lentil (2:1)	38.57	41.51	16.60	16.04	55.17	57.55
Wheat + Lentil (2:2)	35.39	38.07	14.85	14.37	50.25	52.44
SEm±	0.96	1.00	0.45	0.52	1.25	1.39
LSD (P=0.05)	2.80	2.93	1.32	1.50	3.65	4.08

generally more effective at this facilitation than lentil because of its deeper root system and better spatial compatibility with wheat. These observations are supported by Anshumali[13], who found that wheat-based intercropping with pulses improves the nutrient status of the cereal crop under the mid-hill conditions of Palampur.

CONCLUSION

Recommended nutrient management practices were the best among nutrient management practices in terms of yield, nitrogen content in grain and straw, nitrogen uptake by grain and straw and protein content. Wheat + chickpea (2:1) proved to be the best intercropping system in terms of wheat equivalent yield, nitrogen content in grain and straw, protein content and nitrogen uptake by grain/seed and straw as compared to other wheat-based intercropping systems.

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CONFLICT OF INTEREST

Authors declare no competing interest.

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AUTHORS CONTRIBUTION

S: conducted the experiment, analyzed the data and wrote the original manuscript. JS and RK: conceptualized the research programme, methodology, provided resources, reviewed and edited the manuscript. NKS: helped in interpretation of results and discussion. BBR, NAX and ST: Table formulation, and framework of manuscript.