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**Research Paper**

# Productivity and economics of wheat (*Triticum aestivum*) + chickpea (*Cicer arietinum*) intercropping under irrigation and nutrient management

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## ABSTRACT

A field experiment was conducted during 2012–13 and 2013–14 on a silty clay-loam soil of Palampur, Himachal Pradesh, to study the productivity and economics of wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.]+ chickpea (*Cicer arietinum* L.) intercropping under irrigation and nutrient management. Growth, yield attributes, grain and straw yields of wheat and chickpea were affected significantly with irrigation and nutrient-management practices. The irrigated condition resulted in higher wheat-equivalent yield and benefit: cost ratio over rainfed condition. Integrated nutrient management (INM), being statistically at par with organic nutrient management, recorded the highest wheat-equivalent yield over inorganic nutrient management and farmer's practice. Organic nutrient management recorded higher net returns (₹32.6 × $10^3$/ha), whereas INM recorded higher benefit: cost ratio (1.92). Higher values of available nitrogen (215.3 kg/ha), phosphorus (37.1 kg/ha) and potassium (177.3 kg/ha) in soil were recorded in INM than the other nutrient-management practices.

***Key words***: Inorganic, Intercropping, Organic, Rainfed, Wheat, Chickpea

Intercropping is an age-old practice of growing two or more crops simultaneously on the same piece of land. Intercropping has been recognized as a potentially beneficial system of crop production and evidences indicate that it can provide substantial yield advantage over sole cropping (Tsubo *et al*., 2005). Under mid-hill conditions of Himachal Pradesh, an intercropping of chickpea in wheat provides additional source of income to the poor farmers, more efficient use of land and labour, better control of weeds, insects/pests, and pathogens than the sole crops. Intercropping of chickpea in wheat has gained interest because of potential advantage it offers to the crops, i.e. improved utilization of growth resources by the crops and hence increased productivity (Giller and Wilson, 1991). In irrigated conditions, wheat + chickpea intercropping system gives higher yield, improves water-use efficiency and reduces weed growth as the space between the wheat rows is occupied by the intercrop. In rainfed condition, an intercropping with legumes prevents the complete failure of crop as these crops can produce some quantity even under dry conditions. Intercropping mainly with legumes improves the soil fertility both in rainfed and irrigated conditions by fixing atmospheric nitrogen.

The use of organic manures has assumed greater significance in the present set up of agriculture. No doubt, the application of higher dose of inorganic fertilizers promotes better growth of the plant, but at the same time it can also encourage lodging and increase cost of cultivation. Also, the present level of fertilizer production may not be enough to meet the actual demand in near future. Use of vermicompost and vermiwash brings about gradual improvement in soil structure, soil health, productivity and soil-microbial diversity which results in higher crop yields owing to enhanced plant nutrients (Hargreaves *et al*., 2008). So, the addition of organic manures and biofertilizers in combination with chemical fertilizers may be helpful and serve as a supplementary source of nutrients in economizing the use of fertilizers. Teklu and Hailemariam (2009) reported that soil-fertility maintenance requires a balanced application of organic and inorganic sources of nutrients. Keeping in view these aspects, there is a dire need to compare the effect of organic and

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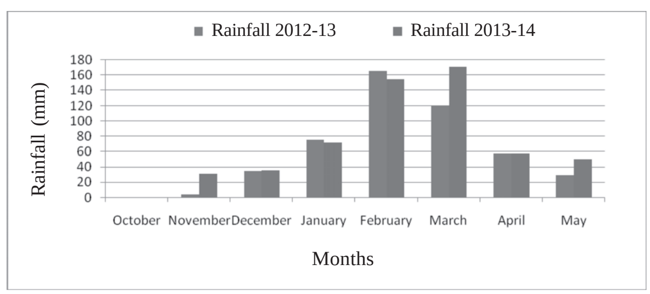
inorganic sources of nutrients on productivity of crops and soil health. Therefore, an experiment was conducted during 2012–13 and 2013–14 to study the response of wheat + chickpea intercropping system to organic and inorganic sources of nutrients.

## MATERIALS AND METHODS

A field experiment was conducted during the winter (*rabi*) seasons of 2012–13 and 2013–14 at Model Organic Farm, Department of Organic Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (32°4 N, 76°3 E, about 1,224 m above mean sea level). The experiment was conducted on silty clay-loam soil, having *p*H 5.1, organic C 1.10%, available N 199.3 kg/ha, available P 32.1 kg/ha and available K 170.8 k/ha. The experiment was laid out in split plot design with irrigation treatments in main plot and nutrient management in a sub-plot using three replications. The experiment consisted of 2 irrigation treatments, i.e. irrigated and rainfed in main plots and 8 treatments comprising of combinations of 4 nutrient management-practices, i.e. organic (soil treatment with jeevamrit + seed treatment with *Azospirillum*/*Rhizobium* and phosphate-solubilizing bacteria (PSB) + vermicompost 10 t/ha having moisture content 25% + 3 sprays of vermiwash), inorganic (recommended NPK), integrated (5 tonnes VC + 50% of recommended NPK) and farmer's practice (2.5 tonnes VC + 25% of recommended NPK) in subplots. The present experiment was conducted in permanent plots of rice-wheat + chickpea cropping system since rainy season (*kharif*) 2012. Wheat 'HPW 155' and chickpea 'Himachal Chana 1' were sown on 27 and 28 October during 1 and 2 year respectively. Wheat and chickpea were sown in the ratio of 1:1 and the row spacing was 25 cm between 2 crops. Seed rate of 50 kg/ha for wheat and 20 kg/ha for chickpea was used. The recommended dose of NPK used in wheat crop was N : $P_2O_5$ : $K_2O$ 80 : 40 : 40 kg/ha in rainfed condition and N : $P_2O_5$ : $K_2O$ 120 : 60 : 40 kg/ha in irrigated condition, respectively. Half dose of nitrogen and whole $P_2O_5$ and $K_2O$ were incorporated in soil, as per the treatments, as basal dose and remaining nitrogen was top-dressed at tillering stage of the wheat crop. No additional dose of fertilizer was added to chickpea crop. Nutrient content of vermicompost used was 1.5% N, 1.0% P and 0.6% K. The quantity of nutrients added in different management practices was N : $P_2O_5$ : $K_2O$ 113 : 75 : 45 kg/ha in organic, N : $P_2O_5$ : $K_2O$ 80 : 40 : 40 kg/ha (rainfed) and N : $P_2O_5$ : $K_2O$ 120 : 60 : 40 kg/ha (irrigated) in inorganic, N : $P_2O_5$ : $K_2O$ 56 : 38 : 23 kg/ha + N : $P_2O_5$ : $K_2O$ 80 : 40 : 40 kg/ha (rainfed) and N : $P_2O_5$ : $K_2O$ 120 : 60 : 40 kg/ha (irrigated) in integrated and N : $P_2O_5$ : $K_2O$ 28 : 19 : 11 kg/ha + N : $P_2O_5$ : $K_2O$ 80 : 40 : 40 kg/ha (rainfed) and N : $P_2O_5$ : $K_2O$ 120 : 60 : 40 kg/ha (irrigated) in famer's practice. Microbial counts of different microbes in vermiwash and *jeevamrit* are presented in Table 1. Vermiwash is a brown coloured leachate from washing of worms, which is a cocktail of excretory products, soluble plant nutrients in addition to some organic acids, mucus of earthworms, microbes and macro-micronutrients from soil organic molecules and beneficial micro–organisms. *Jeevamrit* is a solution containing cow urine 1 L, cowdung 1 kg, jaggery 200 g, gram flour 200 g, fertile soil 100 g and 20 L water with proper stirring. Foliar application of vermiwash was done at tillering, jointing and ear-formation stages of wheat. Two hand-weedings were done for weed management 25 and 78 days after sowing during the first year and 29 and 84 days after sowing during the second year. After pre-sowing irrigation, crop was irrigated twice with flood irrigation 20 and 181 days after sowing during the first year and 23 and 177 days after sowing during the second year. Rainfall data during the whole period of experimentation are presented in Fig. 1, which depicted that there was uniform distribution of rainfall from December to May during both the years. Rainfall received during crop




*Source:* Department of Agronomy, CSK HPKV, Palampur

**Fig. 1.** Rainfall data of the study period

**Table 1.** Count of different microbes in vermiwash and *jeevamrit*

| Organic inputs | Microbial count (log cfu/ml) | | | | | | pH |
|---|---|---|---|---|---|---|---|
| | Bacteria | Fungi | Actinomycetes | *Azotobacter* | *Rhizobium spp.* | Phosphate-solubilizers | |
| Vermiwash | 5.90 | 3.55 | 5.45 | 4.35 | 4.28 | 5.80 | 7.50 |
| Jeevamrit | 6.08 | 2.70 | 4.90 | 4.49 | 4.08 | ND | 7.00 |

***Source***: Department of Agronomy, CSK HPKV, Palampur period of 2012–13 and 2013–14 was 483.8 and 569.4 mm respectively. Soil samples were collected during both the years after crop harvesting. The available N content of soil was analysed by micro-kjeldahl's method, P by Olsen's method and K by flame photometer method. Benefit: cost ratio was worked out by dividing gross returns (₹/ha) with cost of cultivation (₹/ha). Since data followed the homogeneity test, pooling was done over the seasons and mean data are presented. Wheat-equivalent yield was calculated on the basis of market price of wheat ₹13/kg and chickpea ₹40/kg.

## RESULTS AND DISCUSSION

### *Yield attributes and yield of wheat*

Irrigated condition resulted in significantly more number of effective tillers/m$^2$ and number of grains/spike over rainfed condition (Table 2). It may be owing to optimum moisture regime which is very important for the balanced metabolic activities of the plants which in turn might have resulted in enhancing these characters. However, spike length and 1,000-grain weight of wheat remained unaffected. Among the nutrient-management treatments, integrated nutrient management (INM) resulted in significantly higher number of effective tillers/m$^2$ and number of grains/spike as compared to the other treatments; and statistically at par with inorganic nutrient management in case of effective tillers/m$^2$. Spike length and 1,000-grain weight remained unaffected with the application of various nutrient management treatments. The beneficial effect of nitrogen and vermicompost on crop growth influenced the yield-attributing characters, positively. The increase in number of tillers/m$^2$ and grains/spike could be attributed to the balanced nutrients supply in INM. Kachroo and Razdan (2006) also reported similar findings.

Significantly higher grain yield and straw yield of wheat were obtained under irrigated condition over rainfed condition (Table 2). Among the nutrient management, INM resulted in significantly higher grain and straw yields of wheat than inorganic and farmer's practice, which might be owing to increased yield attributes under INM which ultimately led to increase in grain yield (Pandey *et al*., 2009). Harvest index remained unaffected under different treatments. Less difference in rainfed and irrigated wheat yield was observed because the dates of irrigation were closer to the dates of sudden rainfall during both the years of crop-growth period.

### *Yield attributes and yield of chickpea*

Significantly higher pods/plant and seeds/pod were recorded in irrigated condition over rainfed condition (Table 3) because of the reason that sufficient soil moisture in root zone might have enabled the plant to provide more number of pods/plant. Among the nutrient-management treatments, organic nutrient management produced significantly higher number of pods/plant and seeds/pod, however, it was statistically at par with INM for seeds/pod.

Significant increase in seed and straw yields of chickpea was recorded in irrigated condition over rainfed. Among the nutrient management treatments, higher seed and straw yields were obtained with organic nutrient management than the other treatments. However, it was statistically at par with INM. The increased seed yield in organic condition might be owing to better availability of nutrients throughout the crop growth that ultimately improved the growth and yield contributing characters of chickpea and hence resulted in higher seed yield. Similar findings were also observed by Singh *et al*. (2004).

### *Wheat-equivalent yield and economics*

Wheat-equivalent yield reflects the total productivity of the intercropping system (Table 4). Irrigated condition resulted in significantly higher wheat-equivalent yield than

**Table 2.** Effect of treatments on yield attributes and yield of wheat (pooled data of 2 years)

| Treatment | Effective tillers/m$^2$ | Spike length (cm) | Grains/ spike | 1,000-grain weight (g) | Grain yield (t/ha) | Straw yield (t/ha) | Harvest index (%) |
|---|---|---|---|---|---|---|---|
| *Soil-moisture regime* | | | | | | | |
| Rainfed | 150 | 10.9 | 49.6 | 56.7 | 2.33 | 4.91 | 32 |
| Irrigated | 163 | 11.2 | 55.5 | 59.4 | 2.82 | 5.23 | 35 |
| SEm± | 3 | 0.6 | 1.0 | 1.5 | 0.05 | 0.10 | 1 |
| CD (P=0.05) | 10 | NS | 3.3 | NS | 0.19 | 0.31 | NS |
| *Nutrient management* | | | | | | | |
| Organic | 148 | 11.0 | 50.6 | 57.1 | 2.60 | 5.05 | 33 |
| Inorganic | 166 | 11.4 | 54.9 | 59.3 | 2.78 | 5.51 | 34 |
| Integrated | 168 | 11.3 | 59.1 | 60.0 | 2.86 | 5.67 | 33 |
| Farmer's practice | 144 | 10.5 | 45.6 | 55.8 | 2.05 | 4.05 | 34 |
| SEm± | 4 | 0.7 | 1.3 | 2.9 | 0.07 | 0.10 | 1 |
| CD (P=0.05) | 11 | NS | 3.9 | NS | 0.21 | 0.30 | NS |

rainfed. Similarly, INM resulted in significantly higher wheat-equivalent yield over farmer's practice and was statistically at par with organic and inorganic nutrient management.

Similar to system productivity, higher net returns and benefit: cost ratio were recorded under irrigated condition. Among nutrient management, organic management recorded the highest net returns; however, it was statistically at par with INM. The lowest benefit: cost ratio was recorded under farmer's practice.

### *Interaction effect*

The interaction effect between nutrient-management practices and soil-moisture regimes was significant in respect of wheat-equivalent yield (Table 5). Under rainfed condition, INM resulted in the highest wheat-equivalent yield among all the other treatments and was statistically at par with inorganic nutrient-management. In irrigated condition, organic nutrient-management resulted in significantly the highest wheat-equivalent yield compared to the other treatments.

The interaction between same or different soil-moisture regimes and nutrient-management practices resulted in significantly higher wheat-equivalent yield with the combination of irrigated condition and organic nutrient management. Irrespective of different nutrient management practices, irrigated condition recorded significantly higher wheat-equivalent yield than rainfed condition.

### *Soil-nutrient status after harvesting*

Soil *p*H and organic carbon remained unaffected with soil-moisture regimes and nutrient management sources. Significantly higher available N in soil was recorded under irrigation than rainfed condition (Table 6). Dutta and Mondal (2006) reported that supply of irrigation provides adequate moisture to soil, which plays an important role in

**Table 3.** Effect of treatments on yield attributes and yield of chickpea (pooled data of 2 years)

| Treatment | Plants/$m^2$ | Pods/plant | Seeds/pod | 1,000-seed weight (g) | Seed yield (t/ha) | Straw yield (t/ha) |
|---|---|---|---|---|---|---|
| *Soil-moisture regime* | | | | | | |
| Rainfed | 15 | 16.8 | 1.5 | 158.5 | 0.28 | 0.52 |
| Irrigated | 16 | 18.2 | 1.8 | 165.9 | 0.37 | 0.62 |
| SEm± | 0.63 | 0.4 | 0.1 | 4.2 | 0.02 | 0.02 |
| CD (P=0.05) | NS | 1.2 | 0.3 | NS | 0.06 | 0.06 |
| *Nutrient management* | | | | | | |
| Organic | 16 | 20.0 | 1.9 | 164.2 | 0.41 | 0.74 |
| Inorganic | 15 | 17.2 | 1.6 | 161.3 | 0.28 | 0.48 |
| Integrated | 17 | 18.1 | 1.8 | 162.5 | 0.34 | 0.62 |
| Farmer's practice | 14 | 14.8 | 1.3 | 160.8 | 0.25 | 0.43 |
| SEm± | 1 | 0.4 | 0.1 | 8.2 | 0.02 | 0.02 |
| CD (P=0.05) | NS | 1.3 | 0.2 | NS | 0.07 | 0.06 |

**Table 4.** Effect of treatments on wheat-equivalent yield and economics of wheat + chickpea intercropping systems (pooled data of 2 years)

| Treatment | Wheat equivalent yield (t/ha) | Cost of cultivation (× $10^3$ ₹/ha) | Gross returns (× $10^3$ ₹/ha) | Net returns (× $10^3$ ₹/ha) | Benefit: cost ratio |
|---|---|---|---|---|---|
| *Soil-moisture regime* | | | | | |
| Rainfed | 3.18 | 30.6 | 52.5 | 21.8 | 1.71 |
| Irrigated | 3.94 | 32.0 | 63.7 | 31.7 | 1.98 |
| SEm± | 0.08 | – | 1.4 | 1.4 | 0.04 |
| CD (P=0.05) | 0.25 | – | 4.3 | 4.3 | 0.12 |
| *Nutrient management* | | | | | |
| Organic | 3.86 | 35.8 | 68.4 | 32.6 | 1.91 |
| Inorganic | 3.64 | 30.5 | 57.9 | 27.4 | 1.90 |
| Integrated | 3.91 | 32.1 | 61.6 | 29.6 | 1.92 |
| Farmer's practice | 2.82 | 26.9 | 44.6 | 17.7 | 1.66 |
| SEm± | 0.10 | – | 1.4 | 1.4 | 0.05 |
| CD (P=0.05) | 0.30 | – | 4.3 | 4.3 | 0.15 |

**Table 5.** Interaction effect of treatments on wheat equivalent yield

| Nutrient management | Wheat-equivalent yield (t/ha) Soil-moisture regimes | |
|---|---|---|
| | Rainfed | Irrigated |
| Organic | 2.99 | 4.73 |
| Inorganic | 3.48 | 3.79 |
| Integrated | 3.71 | 4.10 |
| Farmer's practice | 2.52 | 3.12 |
| | SEm± | CD (P=0.05) |
| To compare nutrient-management practices at same soil-moisture regime | 0.13 | 0.39 |
| To compare soil-moisture regimes at same or different nutrient management practices | 0.13 | 0.40 |

**Table 6.** Effect of irrigation and nutrient management in soil chemical properties (pooled data of 2 years)

| Treatment | *p*H | Organic carbon (%) | N (kg/ha) | $P_2O_5$ (kg/ha) | $K_2O$ (kg/ha) |
|---|---|---|---|---|---|
| *Soil -moisture regime* | | | | | |
| Rainfed | 5.2 | 1.12 | 200.6 | 32.7 | 171.4 |
| Irrigated | 5.2 | 1.17 | 208.8 | 34.6 | 173.8 |
| SEm± | 0.2 | 0.04 | 2.5 | 2.0 | 3.2 |
| CD (P=0.05) | NS | NS | 7.6 | NS | NS |
| *Nutrient management* | | | | | |
| Organic | 5.2 | 1.25 | 208.5 | 35.4 | 174.6 |
| Inorganic | 5.2 | 1.10 | 201.7 | 32.5 | 171.8 |
| Integrated | 5.3 | 1.15 | 215.3 | 37.1 | 177.3 |
| Farmer's practice | 5.1 | 1.09 | 193.3 | 29.7 | 166.7 |
| SEm± | 0.4 | 0.12 | 2.8 | 1.1 | 1.7 |
| CD (P=0.05) | NS | NS | 8.4 | 3.2 | 5.1 |
| Initial status | 5.1 | 1.10 | 199.3 | 32.1 | 170.8 |

increasing the soil-available N. However, available P and K in soil remained unaffected. Among the nutrient-management treatments, INM significantly influenced the available NPK in soil over other treatments; however, it was at par with organic nutrient management in case of P and K. The increase in available N in soil by INM might be owing to the fact that mixing of nitrogen fertilizer and vermicompost have reduced the nitrogen losses, improved fertilizer-use efficiency and thus increased the availability of nitrogen. The addition of organic matter in soil might have decreased the phosphate fixation due to the formation of phosphohumic complexes that easily assimilated by plants which ultimately increased the available P in soil. The increase in available K in soil might be owing to the fact that addition of organic matter in soil have increased the cation-exchange capacity, reduced the leaching losses which ultimately increased the availability of K in soil. Thus the combined application of organic and inorganic manures significantly increased the available NPK status of soil in wheat (Devi *et al.,* 2011).

Irrigated condition and INM recorded higher system productivity and economics in wheat + chickpea intercropping system. Therefore, for higher productivity and profitability from wheat + chickpea system irrigation and INM may be used in silty clay-loam soil of mid-hill region of Himachal Pradesh.

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