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Research Article

# Wheat Response to NPK Nutrients and Its Economics in Punjab Province

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## Abstract

Balanced use of fertilizer is important to achieve optimum yields of wheat. Present study was conducted at farmers' fields in Rice-Wheat and Central mixed cropping zones of Punjab Pakistan for four years from 2019-20 to 2022-23. The objectives of the study were to determine economic optimum dose of nitrogen, phosphorus and potash nutrients for obtaining optimum wheat yields under irrigated conditions. The levels of N used in this study were (0, 53, 106, 160 and 212), for $P_2O_5$ were (0, 57, 114 and 171) and for $K_2O$ were (0, 30, 60) kg $ha^{-1}$ of nutrients. These levels were incorporated in 11 treatments combination according to FAO central rotatory design. All P and K were applied at sowing whereas half N was applied at sowing and remaining N was top dressed at first irrigation. Results of 56 field trials conducted in these two zones indicated that 160 and 114 kilograms of N and $P_2O_5$ respectively per hectare proved economical doses for getting highest wheat grain yield in both these cropping zones. However, for $K_2O$, the economical doses were 30 and 60 kg $ha^{-1}$ for central and rice zones respectively. The study will help revisiting the current fertilizer recommendations. More experimentation is needed to go for imparting site-specific nutrient recommendations for economical crop production.

**Keywords**: Nitrogen; Phosphorus; Potassium; Wheat; Yield; MRR



## Introduction

Wheat is a staple food of millions in Pakistan. For getting optimum yields of wheat, balanced fertilizers play very important role among other factors. Balanced fertilization ensures better crop production and optimizes the nutrient use efficiency, thereby



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sustaining yields on low input agro-ecosystems (Irfan *et al.*, 2019). Most of the developing countries are facing the deficiency of major nutrients in their soils, due to energy crises, increase in fertilizer prices and limited reserves of rock phosphates. The right dose of fertilizer application with respect to local area soil type and climatic condition results increase in the wheat productivity (Sileshi *et al.*, 2022). Appropriate fertilizer management practices, without over reliance on single nutrient use, can correct the deficiency of NP and Zn which are the most limiting nutrients in the rice-wheat soils (Panwar *et al.*, 2018; Singh and Singh, 2018). Yuan *et al.* (2022) reported that optimal level of nitrogen plays vital role in improving nutrient use efficiency and agronomic performance of wheat with increased economic returns. Balanced use of NPK generates significantly higher net income mainly by reducing cost of production and increasing economic yield of wheat. Balance fertilization is a realistic solution to maintain the sustainability of RWCS through appropriate supply of nutrients. Findings of the study conducted by (Sapkota *et al.*, 2020) suggested that N fertilizer application in wheat and rice provided most economical returns when N was applied in between 120–200 kg N $ha^{-1}$ in rice and 50–185 kg $ha^{-1}$ in wheat. Wang *et al.* (2019) reported that optimal rates of fertilizer significantly affect grain yield, nitrogen use efficiency (NUE), nutrient balance and benefit cost ratio. Study reported by (Dargie *et al.*, 2022) suggested that agronomic efficiency of wheat decreased with increasing rates N and P on all soil types. Balanced nutrition increases a plant's ability to absorb requisite amounts of desired nutrients and thus, improve crop productivity and input use efficiency. Wang *et al.* (2023) observed that higher N application rates, the use of coated fertilizers of N, fertilization after anthesis, and multiple nitrogen applications showed enhanced benefits in terms of yield, protein contents and water productivity for wheat crop. They also found that applying N between 100–200 kg $ha^{-1}$ may be optimal rate for maximizing yield.

The information related to fertilizer response by wheat is available only for other areas or in the farm of single on-farm or off-farm experiments. However, for developing fertilizer recommendations for farmers on zone basis, the response of crop to application of nutrients needs to be studied at farmer fields at multiple locations in these zones. However, there is little information available on response of wheat at farmers' fields to soil application of NPK in rice-wheat zone and in Central zone.  Therefore, this study was conducted to evaluate response of wheat to NPK at farmers' fields in Rice and Central zone including economics of the nutrient levels.

## Methodology

### Locations

Current study was carried out at fifty-six sites at farmers' fields (Table 1) in Central (mixed cropping) zone and Rice-wheat zone of the Punjab. In brief, the Rice-wheat zone includes Lahore and Gujranwala divisions whereas the Central mixed cropping zone comprises of Faisalabad, Sargodha and Sahiwal Divisions. The districts included Lahore, Sheikhupura, Kasur, Gujranwala, Hafizabad, Sialkot, Narowal, Sargodha, Sahiwal, Pakpattan, Okara, Faisalabad, Jhang, Toba Tek Singh and Chiniot. Every year study was conducted at new fields to make it representative of diverse conditions in these zones. The districts are shown in figure 1.



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Table 1. Divisional headquarters in rice-wheat and central zones.

| Sr. No | Divisional headquarters | Latitude | Longitude |
|---|---|---|---|
| 1 | Faisalabad | 31.403132° | 73.049464° |
| 2 | Gujranwala | 32.190671° | 74.181446° |
| 3 | Sargodha | 32.085100° | 72.655988° |
| 4 | Lahore | 31.472118° | 74.243136° |
| 5 | Sahiwal | 30.640074° | 73.118855° |


Figure 1. Map of districts of province Punjab, Pakistan.

**Soils and Climate**

The area consists of alluvial soils. The climate of these two zones falls under semi-arid climate. The main growth and grain filling period for wheat extends from mid-November to end of March whereas maturity phase occurs in April and harvested in mid of April. The temperature data during December to March is given here. In Rice-wheat zone (taking Lahore as reference), long term mean minimum temperatures vary from 7.6 to 15.7 °C from November to March and long term mean maximum temperatures vary from 18.4 to 27.5 °C. These averages also include a part of the research study. In Central zone (Faisalabad as reference), mean minimum temperatures vary from 4.8 to 12.6 and mean maximum temperatures vary from 19.4 to 27.4 °C (pakmet.com).

**Experimental Design**

The study was conducted at farmers' fields with randomized layout at all sites (RCBD) with three replications per site. This design is called central rotatory design recommended by FAO. $T_5$ in this design is current recommended dose and other levels of N, P and K rotate around this level. The treatments in this study are given in Table 2. Fertilizer was applied to all treatment sub plots uniformly according to the design. Half N, all P and K was applied to soil at sowing through broadcast. Remaining half N was applied to the crop as top dressing at first irrigation. Sowing of wheat was done in third week of November. Seed rate was 100 kg $ha^{-1}$. Latest approved varieties of wheat of that time were grown in these experimental sites. These included Faisalabad 2008 (45), Akbar



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2019 (3), Dilkash (3), Bhakkar Star (2), Subhani (1), Fakhre Bhakkar (1) and Arooj (1). Since combined recommendations will be given for all varieties in the field on the basis of this study, therefore, inclusion of a number of varieties in this study strengthens the outcome of this study. Moreover, use of diverse varieties by farmers also necessitates the study to be carried out on all varieties in the field. All other cultural practices regarding irrigation, weed control etc. were practiced according to recommended procedures. The experiment was conducted under irrigated conditions (canal water + tubewell water when needed). Yield data were collected by harvesting subplots from experimental units in mid of April. Subsamples were threshed manually and yield data were collected.

Table 2. Treatment nutrients in kg $ha^{-1}$.

| Treatment No | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|
| 1 | 0 | 0 | 0 |
| 2 | 0 | 114 | 60 |
| 3 | 53 | 114 | 60 |
| 4 | 106 | 114 | 60 |
| 5 | 160 | 114 | 60 |
| 6 | 212 | 114 | 60 |
| 7 | 160 | 0 | 60 |
| 8 | 160 | 57 | 60 |
| 9 | 160 | 171 | 60 |
| 10 | 160 | 114 | 0 |
| 11 | 160 | 114 | 30 |

**Soil Sample Collection and Analysis**

Soil samples were collected in a zig zag pattern from all study sites (from 0-15 cm depth). Individual samples were mixed to make composite sample. Samples were taken to the laboratory for analysis of soil chemical and fertility status. At lab, the soil samples were air dried under a shade, ground and passed through 2 mm sieve for analysis. Electrical conductivity (EC) and pH of soil samples were analyzed according to the methods described by (Jackson, 1973). Organic matter (SOM) of study sites was determined using Walkley and Black titration method narrated in (Nelson and Sommers, 1996). Whereas, available phosphorus in soil was determined using Olsen's method (Olsen *et al.*, 1982) using 0.5M sodium bicarbonate as extracting agent. Extractable potassium from soils was determined through aspirating 1N ammonium acetate extract on flame photometer.

**Statistical Analysis**

Statistical analysis of yield data was done by using analysis of variance (ANOVA) techniques. Methods of analysis described by (Gomez and Gomez, 1984) were used for analyzing statistical variability.

**Economic Analysis of Nutrients**

The economics of all levels of N, P and K application to wheat was calculated using two methods i.e. firstly through benefit cost ratio and secondly through MRR (Marginal rate



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of return) technique individually for N, P and K nutrients. Benefit cost ratio was calculated by following method.

Benefit cost ratio= Value of wheat grain ÷ nutrient cost……(i)

Marginal rate of return of individual nutrients was calculated with following equation.

Marginal rate of return (MRR) = Marginal Revenue ÷ Marginal nutrient cost ……(ii)

Where marginal revenue is value (in Rs) of additional wheat grain yield with using upper level of a nutrient as compared to the yield using previous lower level of that particular nutrient. Cost benefit ratio was simply the ratio of value of produce divided by nutrient cost.

## Results and Discussion

**Soil characteristics of experimental sites**

All experimental sites had normal pH of less than 8.5, so free from sodicity hazard (Table 3, 4). Moreover, electrical conductivity of saturated soil extract was between 0.66 and 3.5 dS $m^{-1}$, hence less than 4.0 dS $m^{-1}$ and free from salinity problem. Organic matter of these experimental sites ranged between 0.40 to 1.70 percent. Average available phosphorus contents in soils ranged between 3.9 to 8.6 ppm. The soils having less than 8.0 are classified as poor for P. Most of the soils were poor in available phosphorus. Generally, extractable soil potash in central zone was relatively higher than rice zone.

**Effect of NPK levels on wheat grain yield**

Grain yields of wheat varied considerably during four years of study (Tables 5, 6).

**Nitrogen**

Wheat grain yield was increased upto application of N to the level of 160 kg $ha^{-1}$ ($T_4$) during all the years in this study in both the zones. Further increasing the dose of N to 212 kg $ha^{-1}$ ($T_5$) did not improve the grain yield further. Current recommended dose of N is 160 kg $ha^{-1}$.

**Phosphorus**

Maximum grain yield averaged 5042 and 4806 kg $ha^{-1}$ in rice and central zones respectively with $P_2O_5$ @ 171 kg $ha^{-1}$ ($T_9$). Current recommendation of $P_2O_5$ is 114 kg $ha^{-1}$.

**Potash**

In rice zone, wheat responded positively to application of $K_2O$ @ 60 kg $ha^{-1}$. However, in central zone, wheat only responded up to 30 kg $ha^{-1}$ of $K_2O$. The reason for better response to higher doses of K in rice soils may be the lower soil K levels in rice zone and relatively higher K levels in central zone.

Table 3. Pre-sowing soil analyses of experiment sites (2019-20 to 2020-21).

| Soil Parameters | 2019-20 | | | | 2020-21 | | | |
|---|---|---|---|---|---|---|---|---|
| | Rice zone 8 sites | | Central zone 17 sites | | Rice zone 4 sites | | Central zone 11 sites | |
| | Avg. | Range | Avg. | Range | Avg. | Range | Avg. | Range |
| EC (dS $m^{-1}$) | 1.25 | 0.70-2.10 | 2.32 | 1.20-3.40 | 1.5 | 0.8 - 2.4 | 2.0 | 1.2 - 3.5 |
| pH | 7.9 | 7.7-.8.2 | 8.2 | 7.7-8.4 | 8.0 | 7.7 - 8.2 | 8.2 | 7.7 - 8.4 |
| O.M.% | 0.62 | 0.40-0.80 | 0.76 | 0.53-1.00 | 0.7 | 0.7 - 0.8 | 0.90 | 0.40 - 1.7 |
| Available P (ppm) | 6.4 | 4.0-10.2 | 7.0 | 4.9-12.1 | 3.9 | 1.1 - 5.8 | 5.6 | 2.5 - 7.9 |
| Extractable K (ppm) | 142 | 100-178 | 186 | 100-280 | 101 | 42 - 137 | 155 | 120 - 180 |



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Table 4. Pre sowing soil analysis of experimental sites (2021-22 to 2022-23)

| Soil Parameters | 2021-22 | | | 2022-23 | | | |
|---|---|---|---|---|---|---|---|
| | Rice zone 1 site | Central zone 7 sites | | Rice zone 2 sites | | Central zone 6 sites | |
| | Value | Avg. | Range | Avg | Range | Avg. | Range |
| EC (dS $m^{-1}$) | 1.50 | 1.50 | 1.07 -0.98 | 0.70 | 0.66 - 0.80 | 1.90 | 1.00 - 3.10 |
| pH | 7.7 | 7.9 | 7.6 - 8.4 | 8.1 | 7.96 - 8.2 | 8.1 | 7.70 - 8.4 |
| O.M.% | 0.62 | 0.72 | 0.57 - 0.94 | 0.77 | 0.70 - 0.83 | 0.89 | 0.42 - 1.54 |
| Available P (ppm) | 7.6 | 8.6 | 5.7 - 12.5 | 5.0 | 2.9 - 7.0 | 8.1 | 6.6 - 9.5 |
| Extractable K (ppm) | 113 | 165 | 130 - 184 | 52 | 48 - 56 | 163 | 120 – 236 |

Table 5. Effect of various NPK levels on wheat grain yield (t $ha^{-1}$) (Rice Zone)

| Treatments | $N-P_2O_5-K_2O$ | 2019-20 | 2020-21 | 2021-22 | 2022-23 | Average |
|---|---|---|---|---|---|---|
| No. of sites | Kg $ha^{-1}$ | 8 | 4 | 1 | 2 | 15 |
| $T_1$ | 0-0-0 | 1585i | 1731 i | 1711 g | 1639 I | 1640 J |
| $T_2$ | 0-114-60 | 2085h | 2587 h | 2707 f | 2537 H | 2321 I |
| $T_3$ | 53-114-60 | 3293f | 3492 f | 3778 d | 3555 F | 3413 G |
| $T_4$ | 106-114-60 | 3950de | 4175 d | 4481 c | 4127 E | 4069 E |
| $T_5$ | 160-114-60 | 4450b | 4823 bc | 5144 b | 5226 B | 4699 B |
| $T_6$ | 212-114-60 | 4392bc | 4860 b | 5087 b | 5145 B | 4664 B |
| $T_7$ | 160-0-60 | 2907g | 3062 g | 3247 e | 3352 G | 3030 H |
| $T_8$ | 160-57-60 | 3766e | 3743 e | 3794 d | 4134 E | 3811 F |
| $T_9$ | 160-171-60 | 4786a | 5167 a | 5444 a | 5615 A | 5042 A |
| $T_{10}$ | 160-114-0 | 3969d | 4296 d | 4444 c | 4447 D | 4152 D |
| $T_{11}$ | 160-114-30 | 4240c | 4608 c | 4507c | 4772 C | 4427 C |
| | Lsd (0.05) | 199 | 229 | 118 | 107 | 81 |

Response of wheat to application of N, P and K has also been observed in by other authors. Irfan *et al.* (2018) obtained almost similar results in Sindh soils using 150 kg $ha^{-1}$ of N. However, he obtained maximum yield of wheat with 110 kg $ha^{-1}$ of $P_2O_5$. However, in current study, the grain yield was increased upto 171 kg $ha^{-1}$ of $P_2O_5$. Zar Muhammad *et al.* (2016) also obtained 62% more grains with application of 120:60:60 (N:P:K kg $ha^{-1}$) in cereals as compared to no fertilizer. Irfan *et al.* (2018) also reported similar results when he observed the maximum yield and growth related parameters with 150 and 75 kg $ha^{-1}$ of N and $P_2O_5$ respectively.

The zonal average grain yield was plotted against the fertilizer dose to get prediction equations which are given below.

**Rice zone**

$$y = -0.058x^2 + 23.5x + 2314; R^2 = 0.99 \text{ (for N)}$$

$$y = -0.034x^2 + 17.9x + 2998; R^2 = 0.99 \text{ (for P)}$$

$$y = -0.002x^2 + 09.2x + 4152; R^2 = 0.99 \text{ (for K)}$$

**Central zone**

$$y = -0.057x^2 + 22.9x + 2306; R^2 = 0.99 \text{ (for N)}$$

$$y = -0.036x^2 + 17.2x + 2960; R^2 = 0.98 \text{ (for P)}$$



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$$y = -0.054x^2 + 08.0x + 4267; R^2 = 0.99 \text{ (for K)}$$

Where y is expected wheat grain yield and x is the applied nutrient dose, both in kg $ha^{-1}$.

Table 6. Effect of various NPK levels on wheat grain yield (t $ha^{-1}$) (Central Zone)

| Treatments/ Year | $N-P_2O_5-K_2O$ | 2019-20 | 2020-21 | 2021-22 | 2022-23 | Average |
|---|---|---|---|---|---|---|
| No. of sites | Kg $ha^{-1}$ | 17 | 11 | 7 | 6 | 41 |
| $T_1$ | 0-0-0 | 1523i | 1551 i | 1654 j | 1901 J | 1608 J |
| $T_2$ | 0-114-60 | 2224h | 2249 h | 2217 i | 2790 I | 2312 I |
| $T_3$ | 53-114-60 | 3267f | 3378 f | 3197 g | 3787 G | 3361 G |
| $T_4$ | 106-114-60 | 3963d | 4083 d | 4001 e | 4394 E | 4065 E |
| $T_5$ | 160-114-60 | 4358bc | 4622 b | 4561 b | 4977 BC | 4554 B |
| $T_6$ | 212-114-60 | 4422b | 4588 b | 4524 b | 5055 B | 4577 B |
| $T_7$ | 160-0-60 | 3091g | 2990 g | 2666 h | 3117 H | 2995 H |
| $T_8$ | 160-57-60 | 3759e | 3737 e | 3359 f | 3992 F | 3719 F |
| $T_9$ | 160-171-60 | 4666a | 4829 a | 4730 a | 5249 A | 4806 A |
| $T_{10}$ | 160-114-0 | 4066d | 4363 c | 4255 d | 4676 D | 4267 D |
| $T_{11}$ | 160-114-30 | 4290c | 4543 bc | 4397 c | 4860 C | 4460 C |
| | LSD (0.05) | 102 | 180 | 79 | 147 | 41 |

**Economics analysis**

**Nitrogen**

In rice zone, initially benefit cost ratio was increased with increasing dose of N (Tables 7, 8). Maximum grain yield (4699 kg $ha^{-1}$) was obtained in $T_5$. Hence maximum return of Rs 4,58,172 $ha^{-1}$ was obtained in $T_5$ with application of 160 kg $ha^{-1}$ of N. Maximum benefit cost ratio was also obtained with 160 kg $ha^{-1}$ of N. Marginal rate of return with this dose was 13.8 which was optimum. Beyond this dose, application of N did not result in increase in yield; rather it only increased fertilizer cost, which resulted in decreased benefit cost ratio and MRR. Similar pattern was observed for N in central zone, where the benefit cost ratio was maximum (4.15) with 160 kg $ha^{-1}$. Therefore, 160 kg $ha^{-1}$ may be considered as optimum dose of N on the basis of economics also. Irfan *et al.* (2018) also observed 150 kg $ha^{-1}$ of N as most profitable dose on the basis of yield and N and P recovery.

**Phosphorus**

In Rice zone, maximum grain yield of wheat was observed with P@171 kg $ha^{-1}$ ($T_9$). Benefit cost ratio of P got decreased with this level of P. This was due to higher prices of P fertilizers. Benefit cost ratio for increasing P level from 114 to 171 was decreased from 4.28 to 3.67. Moreover, marginal return was only Rs 5684 $ha^{-1}$ with 171 kg $ha^{-1}$ of P. MRR of this level was 1.4 only whereas MRR with previous level of P (114 kg $ha^{-1}$) was 17.1. Therefore, on the basis of benefit cost ratio, marginal return and marginal rate of return, 114 kg $ha^{-1}$ of $P_2O_5$ may be considered as economical dose. Similar trend was observed in central zone also. With increasing P dose from 114 to 171 kg $ha^{-1}$, the marginal return got negative (Rs -3189) alongwith negative MRR (-0.8). Singh (2017) noted that application of 120 kg N+46 kg $P_2O_5$ $ha^{-1}$ was not sufficient for higher yields. But by increasing NPK



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levels up to 150 % increased grain yield by 50.1 and 21.5 and 48.3 and 19.7% over farmers fertilizer practice and government recommended dose respectively.

Table 7: Benefit cost ratio and MRR of NPK fertilizers on wheat grain yield in rice zone.

| Sr. No, | Nutrients $N-P_2O_5-K_2O$ (kg $ha^{-1}$) | Wheat Grain yield (Kg $ha^{-1}$) | Fertilizer Cost (Rs $ha^{-1}$) | Value of wheat grains (Rs $ha^{-1}$) | Benefit cost ratio | Marginal return (Rs $ha^{-1}$) | Marginal rate of return (MRR%) |
|---|---|---|---|---|---|---|---|
| | Nitrogen | | | | | | |
| T1 | 0-0-0 | 1640 | 0 | 1,59,855 | - | - | - |
| T2 | 0-114-60 | 2321 | 69,870 | 2,26,259 | 3.24 | - | - |
| T3 | 53-114-60 | 3413 | 82,150 | 3,32,800 | 4.05 | 97373 | 43.0 |
| T4 | 106-114-60 | 4069 | 94,430 | 3,96,728 | 4.20 | 54759 | 16.9 |
| T5 | 160-114-60 | 4699 | 1,06,942 | 4,58,172 | 4.28 | 52103 | 13.8 |
| T6 | 212-114-60 | 4664 | 1,18,990 | 4,54,695 | 3.82 | -12473 | -2.9 |
| | Phosphorus | | | | | | |
| T7 | 160-0-60 | 3030 | 52,792 | 2,95,458 | 5.60 | - | - |
| T8 | 160-57-60 | 3811 | 79,867 | 3,71,553 | 4.65 | 48337 | 16.4 |
| T5 | 160-114-60 | 4699 | 1,06,942 | 4,58,172 | 4.28 | 58841 | 17.1 |
| T9 | 160-171-60 | 5042 | 1,34,017 | 4,91,595 | 3.67 | 5684 | 1.4 |
| | Potash | | | | | | |
| T10 | 160-114-0 | 4152 | 91,222 | 4,04,781 | 4.44 | - | - |
| T11 | 160-114-30 | 4427 | 99,082 | 4,31,620 | 4.36 | 18978 | 4.7 |
| T5 | 160-114-60 | 4699 | 1,06,942 | 4,58,172 | 4.28 | 18673 | 4.4 |

**Potash**

In rice zone, maximum yield was obtained with application of 60 kg $ha^{-1}$ of $K_2O$. Benefit cost ratio for 60 kg $ha^{-1}$ of $K_2O$ was 4.28 whereas MRR was 4.4 for this dose. This indicated that application of $K_2O$ @ 60 kg $ha^{-1}$ was economical for wheat in rice zone. In central zone, benefit cost ratio of 60 kg $ha^{-1}$ of $K_2O$ was 4.39. However, the marginal rate of return for increasing the dose from 30 to 60 kg $ha^{-1}$ was only 0.3 with a minor increase of Rs 1,348 per ha. Therefore, for central zone, 60 kg $ha^{-1}$ of $K_2O$ appeared to be uneconomical. Hence, $K_2O$ @ 30 kg $ha^{-1}$ may be considered optimum for wheat in central zone. However, for rice zone, the economic optimum dose of $K_2O$ for wheat may be 60 kg $ha^{-1}$. A 10% increase in wheat yield with application of K has also been reported by Huang et al. (2020) while working on winter wheat in Yangtze River catchment in China. However, marginal rate of return should be better as indicated by (Dawadi *et al.*, 2023) where the farmers were constrained for expansion of wheat even with MRR of 1.6.

## Conclusion

Yield response of wheat to N and P application in rice and central zones indicates that 160 and 114 kg $ha^{-1}$ of N and P may be considered as optimum dose of these nutrients. The constraint to application of N and K appears in its response. However, the constraint to the use of P appears in its high price. Therefore, more P may only be economical if its



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price is reduced. Fertilizer use especially P and K may be economical if it is used on the basis of site specific soil analysis.

Table 8: Cost benefit ratio and MRR of NPK fertilizers on wheat grain yield in central zone.

| Sr. No. | Nutrients $P_2O_5$-$K_2O$ (kg ha$^{-1}$) | Wheat Grain yield (Kg ha$^{-1}$) | Fertilizer Cost (Rs ha$^{-1}$) | Value of wheat grains (Rs ha$^{-1}$) | Benefit cost ratio | Marginal return (Rs ha$^{-1}$) | Marginal rate of return (MRR%) |
|---|---|---|---|---|---|---|---|
| | Nitrogen | | | | | | |
| T1 | 0-0-0 | 1608 | 0 | 1,56,799 | - | - | - |
| T2 | 0-114-60 | 2312 | 69,870 | 2,25,453 | 3.23 | - | - |
| T3 | 53-114-60 | 3361 | 82,150 | 3,27,690 | 3.99 | 93068 | 41.3 |
| T4 | 106-114-60 | 4065 | 94,430 | 3,96,314 | 4.20 | 59454 | 18.7 |
| T5 | 160-114-60 | 4554 | 1,06,942 | 4,44,022 | 4.15 | 38366 | 10.2 |
| T6 | 212-114-60 | 4577 | 1,18,990 | 4,46,217 | 3.75 | -6801 | -1.6 |
| | Phosphorus | | | | | | |
| T7 | 160-0-60 | 2995 | 52,792 | 2,92,027 | 5.53 | - | - |
| T8 | 160-57-60 | 3719 | 79,867 | 3,62,593 | 4.54 | 42807 | 14.7 |
| T5 | 160-114-60 | 4554 | 1,06,942 | 4,44,022 | 4.15 | 53663 | 16.0 |
| T9 | 160-171-60 | 4806 | 1,34,017 | 4,68,583 | 3.50 | -3189 | -0.8 |
| | Potash | | | | | | |
| T10 | 160-114-0 | 4267 | 91,222 | 4,16,054 | - | - | - |
| T11 | 160-114-30 | 4460 | 99,082 | 4,34,807 | 4.56 | 10893 | 2.6 |
| T5 | 160-114-60 | 4554 | 1,06,942 | 4,44,022 | 4.39 | 1348 | 0.3 |

## Conflict of Interest

The authors have not declared any conflict of interest.

## Authors Contributions

All the authors contributed equally in the manuscript.

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