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EXPLORING THE BEST NP RATIO FOR WHEAT IN PERSPECTIVE OF PRESENT FARMERS' BUDGET FOR FERTILIZER

Muhammad Nadeem Iqbal[1], Adnan Umair*[2], Zia Chishti[1], Zafar Abbas[3], Hafiz Riaz Ahmad[4], Samina Hamid[5], Nadeem Raza[1], Khalid Mehmood Mughal[6], Mahreen Khalid[4], Iftikhar Haider[6]

[1]*Soil Fertility, AARI, Faisalabad, Pakistan*
[2*]*Soil and Water Conservation Research Station Sohawa, Pakistan*
[3]*Soil Fertility, SWTL, Bahawalpur, Pakistan*
[4]*Soil Fertility Research Institute, Lahore, Pakistan*
[5]*Soil and Water Testing Laboratory, Sheikhupura, Pakistan*
[6]*AARI, Faisalabad, Pakistan*

Abstract

Farming community has a limited budget for various inputs like fertilizers for crops. Farmers usually allocate more money to nitrogen fertilizers while spending less money on phosphorus. Field experiments were carried out at farmers' fields to explore the effect of various ratios of nitrogen and phosphorus fertilizer while keeping the farmers' budget constant. Fertilizer experiments were conducted on wheat in Punjab Pakistan during years 2015-16 to 2017-18 at different locations in Punjab. Five different ratios (4:1, 3:1, 2:1, 1.7:1) of N and P were used with treatments of 152-37-0, 137-46-0, 117-58-0, 108-64-0, 160-114-0. Recommended dose of 160-114-60 kg ha^{-1} of N-P_2O_5-K_2O was also applied for additional information. At maturity, crop was harvested and data of wheat grain for each site were recorded. During the year 2015-16, 12 sites produced higher wheat yield with NP ratio of 1.7:1 (T_4) out of 14 field sites. Similarly in 2016-17, out of 19, 18 experimental sites produced higher grain yield with T_4 as economically best fertilizer combination. Similar results were obtained during 2017-18 with T_4 and out of 17, 15 experimental sites produced comparatively higher grain yield. Recommended dose @ 160-114-60 kg ha^{-1} produced highest grain yield. However, among farmer budget treatments, T_4-a combination of nitrogen@108 kg ha^{-1} and phosphorus@64 kg ha^{-1} gave higher wheat production. It is concluded that farmers can increase the yield of wheat just by balancing the fertilizer and increasing the phosphorus use in place of nitrogen.

Keywords: nitrogen, phosphorus, budget, wheat, grain.

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**Corresponding Author:*
adnanumair@gmail.com

1. INTRODUCTION

Continuous removal of nutrients from soil through intensive crop production results in lowering of soil fertility levels. Failure in replacement of these nutrients develops a stressful environment in soil. This type of stress environment prevails in many agricultural lands of the region and affects the production of crops[1]. Supply of essential nutrients in balanced ratio is very important for increasing crop production in Pakistan as intensive cropping system is causing severe depletion of essential elements from agricultural lands which in turn reduce the fertility level of the soil[27].

In Pakistan, mostly N is the main source of fertilization[3]. Such trends of favoring only one nutrient result in deficiencies of other nutrients especially P which consequently results in reduction of yield goal[21]. Application of nitrogen in excessive amounts not only causes deficiency of other nutrients but also causes yield losses by lodging and delaying maturity of the crop[16]. Phosphorus is an essential macronutrient, as it has vital role in many biochemical reactions related to energy transfer and metabolism of protein and carbohydrate. It is also important structural part of nucleic acid, help in healthy growth of plant root system, maturity of crop and healthy seed development. Deficiency of this element may result in necrosis and even leaf fall[28]. Therefore, application of phosphorus along with nitrogen in balanced ratio is the basic input for obtaining higher yield of wheat.

Increasing production area for wheat is a good strategy, but improvement in yield of cultivated wheat is more important in order to meet the increasing food demand of the increasing population. This improvement in yield is linked with the application of nutrients in a balanced ratio, especially in case of N and P fertilizers as their imbalance dose causes reduction of crop yield[8]. Use of balanced dose of nitrogen and phosphorus is one of the key components of modern agriculture techniques which mean supply of both nutrients to plant not only in required amounts but also in balanced ratio[26]. As application of phosphorus along with nitrogen does not only maintain the fertility status of soil but also lower the nitrogen fertilizer demand by improving the nitrogen absorption through development of healthy root system of plant[2]. Balanced fertilization is not only environment friendly but also budget friendly[14]. Higher quantity of phosphorus may not also contribute towards improved growth rate due to translocation of about 40 to 80 percent of phosphorus in the vegetative parts of plants in wheat and rice grains[25,6]. Similarly, researchers[5] observed temporal decease in phosphorus concentration in vegetative parts of soybean. Hence balanced use of N and P is necessary for optimum crop yield. In future the global need appraisal of P ranged between 22–27 million tons of Phosphorus annually by 2050 for lands under crop and further supplementary 4–12 million tons phosphorus per year for grasslands[19]. Previous studies[11,22] confirmed that the numbers of productive tillers were increased significantly due to the application of phosphorus. Optimal dose of phosphorus has increased the number of grains per spike and 1000 grain weight of wheat[32]. Correspondingly, significant increase in thousand grain weight of wheat was also observed due to phosphorus application[30]. In another study[23], a stoichiometric association between nitrogen and phosphorus concentration of plant leaf has been proved which underpins the linkage of essential metabolic activities. Photosynthesis mainly depends on the N and P contents of the leaf. However, low concentration of phosphorus slows down the photosynthetic activity. Present study was conducted to explore the best ratio of nitrogen and phosphorus nutrients for obtaining higher wheat grain yield while keeping total fertilizer cost at a constant value.

2. MATERIALS AND METHODS

2.1 Study area

Field experiments were conducted at 14, 19 and 17 sites at farmers' fields for three years from 2015-16 to 2017-18. These consisted of 27 and 23 sites in Rice and Central zones respectively in Punjab Province, Pakistan. The sites belonged to divisions of Faisalabad, Sargodha, Lahore and Gujranwala. Lahore and Gujranwala are included in Rice zone where rice-wheat cropping rotation is followed. Central zone consists of Faisalabad and Sargodha divisions which has mixed cropping system. The sites are situated in agriculturally good soils named as Class-I lands by Soil Survey of Pakistan[17]. The area is described as alluvial plains with extensive irrigation facilities comprising canal system supplemented with use of ground water[18].

2.2 Soil analysis

Before sowing, soil samples were collected from all sites and analyzed in the laboratory. Soil pH and electrical conductivity was determined from saturated soil paste using methods described by Jackson (1962). Soil organic matter (OM %) was determined by Walkley-Black method[31]. Available phosphorus in soil was determined with Olsen's method[20] using 0.5M $NaHCO_3$ (pH=8.5) extract. Extractable potassium (Ext. K) in soil was measured using flame photometer after extracting it with 1N ammonium acetate (pH=7).

2.3 Experimental plan

On the basis of fertilizer use data, it was observed that farmers in Pakistan use N-P_2O_5-K_2O @ 152-37-0 kg ha^{-1} for wheat crop whose cost was calculated as Rs. 17089 per hectare. Therefore, first fertilizer treatment (T_1) in this study was 152-37-0 kg ha^{-1} which was equal to average farmer practice. Other treatments were T_2=137-46-0, T_3=117-58-0, T_4=108-64-0 of N-P_2O_5-K_2O (kg ha^{-1}). T_1 to T_4 corresponded to four different NP ratios of (4:1, 3:1, 2:1, 1.7:1) and had almost similar fertilizer cost (Table 1). The idea of keeping fertilizer cost constant and only varying N P ratio was used to keep the cost within present farmers' budget. Moreover, T_5=160-114-0 and T_6=160-114-60 kg ha^{-1} were also added as treatments being the recommended dose for wheat without and with potash respectively for comparison. At all sites, three replications were made using RCBD layout in randomized complete block design. All P and K were applied at the time of sowing. N was applied in two splits, half at sowing and remaining at first irrigation. Other field operations including weed control etc. were carried out according to the need of the site.

Wheat was sown between 15th to 30th of November with recommended seed rate between 100 and 112.5 kilograms per hectare. Only recommended varieties of agriculture department were sown at these sites. Irrigations were applied according to the need. Grain yield data were recorded after manual harvesting.

Statistical and economic analysis:

Data were analyzed statistically by using appropriate statistical techniques[29]. For comparison of treatment means LSD test was applied.

3. RESULTS AND DISCUSSIONS

3.1. Soil analysis

Summary of soil analysis results of experimental sites is given in Table 2. In both rice and central zones (2015-16) (Table 2), electrical conductivity of soil ranged between 0.40 and 2.10 averaging 1.55 dS m^{-1} depicting that the soils were non-saline. Similarly, pH of the soils ranged between 7.6 and 8.4 averaging 8.1 depicting that the soils were normal. Organic matter of the experimental soils was generally lower ranging between 0.50 to 0.97 percent averaging 0.78 and 0.77 percent respectively. Average available phosphorus in two zones was 5.3 and 6.3 ppm respectively showing the dominance of poor soils from phosphorus point of view. Extractable potash was at 122 ppm (medium) and 192 ppm (adequate) level respectively in these two zones. Almost similar soils were used in these field experiments in next two years.

4. EFFECT OF FERTILIZER RATIOS ON GRAIN YIELD

4.1. Overall results

Grain yield data of wheat in rice zone is given in tables 3, 4 and 5 for three years, whereas the data for central zone is given in tables 6, 7 and 8. In Rice zone, during first two years (2015-16 and 2016-17), highest wheat grain yield was obtained with T_6 (4491 and 4892 kg ha^{-1} respectively) with recommended dose of NPK followed by T_5 with same N, P but without potash. However, during 2017-18, T_5 and T_6 were similar but higher than other treatments. The reason of higher yields with T_5 and T_6 was obviously the higher dose of nutrients as compared to T_1-T_4. In Central zone, during first year 2015-16, T_5 and T_6 produced higher but similar yield. However, during next two years viz. 2016-17 and 2017-18, T_6 produced highest grain yield among all treatments. This showed that wheat was responsive to higher levels of nutrients i.e. 160-114-60 kg ha^{-1} with a NP ratio of 1.4:1. These results were in line with the previous studies[28].

Table 1: Treatment details of fertilizer at nutrient prices

Tr. No.	Expenditure to be incurred	NP Ratio	Nutrients (kg ha^{-1})			Exact cost (Rs ha^{-1})
			N	P_2O_5	K_2O	
1	Present farmer fertilizer use	4.0 : 1	152	37	0	17094
2	Fertilizer dose	3.0 : 1	137	46	0	17072
3	Fertilizer dose	2.0 : 1	117	58	0	17042
4	Fertilizer dose	1.7 : 1	108	64	0	17107
5	Recommended fertilizer (excluding potash)	1.4 : 1	160	114	0	27868
6	Recommended fertilizer (including potash)	1.4 : 1	160	114	60	39868
	Nutrients price Rs kg^{-1} (N@80, P@131.6, K@160)					

Table 2. Pre-sowing soil analysis of experimental sites

Soil parameters	2015-16		2016-17		2017-18	
	Rice (8)	Central (6)	Rice (11)	Central (8)	Rice (8)	Central (9)
ECe (dS m^{-1})	1.44	1.73	1.08	2.27	1.67	2.06
pH	8.1	8.1	8.0	8.0	8.0	8.2
OM%	0.78	0.70	0.62	0.74	0.55	0.76
Available P (mg kg^{-1})	5.3	6.3	6.9	6.8	4.3	7.0
Extractable K (mg kg^{-1})	122	192	152	236	122	152

As regards first four treatments (T_1 to T_4) are concerned, T_1 produced lowest grain yield during all the years in both rice and central zones. This lower yield of wheat was perhaps due to insufficient application of phosphorus (P_2O_5 @37 kg ha^{-1}) because the budget for fertilizer was fixed (farmer practice). With increasing level of phosphorus, grain yield generally tended to increase in both rice and central zones. In rice zone, during first year, T_2 to T_4 were similar. However, during subsequent years, increasing the dose of phosphorus increased the grain yield of wheat. During 2015-16 and 2016-17, the increase in yield was observed with T_2 over T_1 but smaller in magnitude. In Rice zone, increasing yield with increasing P was more conspicuous during 2016-17 and 2017-18 with highest yield observed in T_3 and T_4 (statistically similar). Similar results were observed for Central zone during all three years. However, in Central Zone, during 2016-17 and 2017-18, T_4 (P ratio 1.7:1, P_2O_5@64 kg ha^{-1}) provided significantly highest yield with 4199 and 4241 kg ha^{-1} of grain yield which was 16 and 17 percent higher over T_1 (NP ratio 4:1 with P_2O_5@37 kg ha^{-1}). This increase in yield may be due to enhanced nutrient use efficiency which is attributed to nitrogen and phosphorus interaction within the soil[7]. Similar results were obtained in previous studies where it was found that 120 kg nitrogen along with 80 kg phosphorus is the most economical rate for obtaining higher wheat production[12].

Wheat grain yield data of rice zone (on yearly basis) (tables 3, 4, 5), exhibited that there was upto 4% increase in wheat yield in T_2 (NP ratio 3:1) over T_1 (NP ratio 4:1). With further increase in P level in T_3 (NP ratio 2:1), grain yield increased up to 7%. Similarly, 10% increase in wheat yield was observed in T_4 with 108-64 kg ha^{-1} of N-P (NP ratio 1.7:1) over T_1. This increase in yield may be due to nitrogen and phosphorus synchronization mechanism, as addition of phosphorus may also increase the uptake of nitrogen[24]. Similar results were obtained in central zone of Punjab by balancing the ratios of nitrogen and phosphorus. Table 6 shows that there was 2 to 10% increase in wheat yield in T_2 where 3:1 NP ratio was used when compared with T_1 (NP ratio 4:1). Up to 21 and 28% increase in yield was observed in T_3 (NP ratio 2:1) and T_4 (NP ratio 1.7:1) respectively over T_1 (NP ratio 4:1). Similar results have been reported by some other researchers[13,15];

who experienced significant increase in total grain yield of wheat crop due to phosphatic fertilizer application.

Table 3. Grain yield (kg ha^{-1}) of wheat as affected by various fertilizer doses 2015-16 (Rice zone)

Treatments	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7	Site-8	Average
T_1	3839c	3005d	3204e	5552c	4494b	4264c	3030c	3079c	3808d
T_2	3674c	3243c	3244e	6037a	4517 b	4197c	3580ab	3317bc	3976c
T_3	3744c	3340bc	3324d	5659bc	4459 b	4468bc	3363bc	3414b	3971c
T_4	4076b	3431bc	3498c	5904ab	4544 b	4326bc	3446ab	3505ab	4091c
T_5	4417a	3533ab	3598b	6074a	4837a	4621b	3492ab	3610ab	4273b
T_6	4617a	3713a	3987a	6200a	4841a	4990a	3755a	3824a	4491a
LSD (0.05)	202	201	75	316	118	327	391	331	131

Table 4. Grain yield (kg ha^{-1}) of wheat as affected by various fertilizer doses 2016-17 (Rice zone)

Treatments	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7	Site-8	Site-9	Site-10	Site-11	Average
T_1	4974f	4441c	3095c	5094d	3098c	3047e	3400c	4553b	2967e	3939 bc	3283d	3808e
T_2	5230e	4637b	3263c	5157d	3244c	3111d	3402c	4326c	3067de	4191 a	3250d	3898de
T_3	5549c	4525bc	3706b	5123d	3529b	3470c	3359c	4498bc	3167d	4082 ab	3317d	4030cd
T_4	5322d	4556bc	3784b	5408c	3636b	3640b	3405c	4526b	3367c	3785 c	3550c	4089c
T_5	6008b	5063a	3818ab	5955b	3705b	3687b	4496b	4909a	3867b	4142 ab	4083b	4521b
T_6	6424a	5134a	4071a	6199a	4695a	4444a	4691a	5050a	4333a	4256 a	4517a	4892a
LSD (0.05)	96	175	270	117	218	56	125	179	101	236	190	182

Table 5. Grain yield (kg ha^{-1}) of wheat as affected by various fertilizer doses 2017-18 (Rice zone)

Treatments	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7	Site-8	Average
T_1	3242f	3892f	4154e	3181d	3707c	4085c	4100c	4767bc	3891d
T_2	3325e	3951e	4224de	4023c	3657c	4109c	4317b	4765bc	4046cd
T_3	3570d	4033d	4262d	4267b	3770c	4330b	4307b	4843b	4173bc
T_4	3824c	4548c	4461c	4247b	3969b	4112c	4356b	4652c	4271b
T_5	4063b	4855b	4681b	3910c	4711a	4493a	4711a	5217a	4580a
T_6	4285a	4902a	4877a	4546a	4713a	4520a	4730a	5231a	4726a
LSD (0.05)	142	37	106	150	161	132	160	154	205

If site wise response of treatments is considered, it is observed that at most of the sites, the highest yield was observed in T_4. Out of 50 total sites during three years, only 7 sites produced highest yield with T_1 (N:P

ratio 4:1); rest of the sites providing higher yields belonged to T_3 and T_4 having NP ratios of 2:1 and 1.7:1 respectively. The differences in response of wheat to applied nutrients are due to different levels of available nutrients in soils at each experimental site. The soil analysis averages of sites are given in table 2. The increase of yield with increasing levels of P may also be due to higher harvest index. These findings are in agreement with a study[4] which noted that phosphorus application has significant impact on wheat 1000 grain weight and harvest index. However, in another study[9], there was non-significant influence of P on harvest index of wheat. The results of present study also prove the evidence that addition of phosphorus enhances the nitrogen use efficiency of crop[2].

Table 7 shows that highest grain yield was obtained in T_5 and T_6 where recommended dose of NPK was applied having higher fertilizer dose. However, 5 to 10% increase in wheat grain was observed under a common farmers' budget by just changing the levels of N and P in T_2 (NP ratio 3:1) and T_3 (NP ratio 2:1) respectively when compared with T_1 (NP ratio 4:1). By further increasing the level of P in T_4 where NP ratio was 1.7:1, up to 17% more yield was obtained as compared to the treatment where NP ratio as 4:1. Similar results were obtained in previous studies and it was found that 120 kg nitrogen along with 80 kg phosphorus is the economical rate for obtaining higher wheat production[12]. Results of central zone experiments showed 3 to 19% increase in wheat yield in T_2 (NP ratio 3:1) at different experimental sites, as compared to T_1 (NP ratio 4:1). Table 9 showed that by further increasing the level of phosphorus in T_3, there was up to 23% increase in wheat yield when compared with T_1 where low level of phosphorus and high level of nitrogen was used. T_4 (NP ratio 1.7:1) of different experimental sites of central zone showed 6 to 27% more wheat production where 64 kg ha^{-1} phosphorus was applied along with 108 kg ha^{-1}nitrogen as compared to T_1 (NP ratio 4:1) where 37 kg ha^{-1} phosphorus and 152 kg ha^{-1} nitrogen was applied.

Table 6. Grain yield (kg ha^{-1}) of wheat as affected by various fertilizer doses 2015-16 (Central zone)

Treatments	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Average
T_1	2296c	3778d	3213d	3470e	3037d	3722cd	3253d
T_2	2348c	3926cd	3509c	3589de	3352c	3630d	3392cd
T_3	2415c	3963bc	3833b	3693d	3685b	3815c	3567bc
T_4	2498bc	4000bc	3935b	4167c	3898b	4000b	3750b
T_5	2770ab	4111ab	4343a	4444b	4213a	4222a	4017a
T_6	2911a	4241a	4444a	4752a	4380a	4215a	4157a
LSD (0.05)	280	164.8	179.8	165.4	226.4	182	208

Table 7. Grain yield (kg ha^{-1}) of wheat as affected by various fertilizer doses 2016-17 (Central zone)

Treatments	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7	Site-8	Average
T_1	3326e	3963f	3630f	3726f	3637d	4130e	3111e	3326e	3606f
T_2	3644d	4063e	3859e	3911e	3772c	4204de	3426d	3644d	3815e
T_3	4037c	4167d	4230d	4074d	3848c	4315cd	3820c	4037c	4066d
T_4	4156c	4285c	4348c	4333c	4019b	4389c	3907c	4156c	4199c
T_5	4496b	4556b	4478b	4830b	4685a	4611b	4315b	4496b	4558b
T_6	4733a	4889a	4711a	5067a	4770a	4926a	4634a	4733a	4808a

LSD (0.05)	155	63	43	68	127	147	308	155	131

Table 8. Grain yield (kg ha^{-1}) of wheat as affected by various fertilizer doses 2017-18 (Central zone)

Treatments	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7	Site-8	Site-9	Average
T_1	4026d	3985e	3000e	3704f	4019e	3948b	3341f	3111c	3470f	3623f
T_2	4190cd	4126de	3326d	3889e	4367cd	3926b	3708e	3426c	3831e	3865e
T_3	4431bc	4315cd	3704c	4052d	4204de	4030b	3920d	3820b	4030d	4056d
T_4	4603b	4500bc	3815bc	4311c	4593c	4074ab	4124c	3907b	4239c	4241c
T_5	4974a	4719ab	4204b	4807b	5130b	4222ab	4393b	4315a	4547b	4590b
T_6	5069a	5000a	4519a	5044a	5630a	4407a	4495a	4615a	4670a	4828a
LSD (0.05)	351	291	206	66	232	343	24	316	25	145

Table 9. Benefit cost ratio of fertilizer use

Treatments	Grain yield (kg ha^{-1})				Fertilizer Cost (Rs ha^{-1})	Value of grains (Rs ha^{-1})	Benefit cost ratio
	2015-16	2016-17	2017-18	Average			
Rice Zone	A	B	C	D	E	F	G=F/E
T_1	3808	3808	3891	3836	17094	139043	8.13
T_2	3976	3898	4046	3973	17072	144033	8.44
T_3	3971	4030	4173	4058	17042	147103	8.63
T_4	4091	4089	4271	4150	17107	150450	8.79
T_5	4273	4521	4580	4458	27868	161603	5.80
T_6	4491	4892	4726	4703	39868	170484	4.28
Central Zone							
T_1	3253	3606	3623	3494	17094	126658	7.41
T_2	3392	3815	3865	3691	17072	133787	7.84
T_3	3567	4066	4056	3896	17042	141242	8.29
T_4	3750	4199	4241	4063	17107	147296	8.61
T_5	4017	4558	4590	4388	27868	159077	5.71
T_6	4157	4808	4828	4598	39868	166665	4.18

4.2. Economic analysis

Table 9 indicates that T_5 and T_6 produced the highest yield but it also had highest fertilizer input cost (viz. Rs 27868 and 39868 per hectare respectively) which may not be within the budget of farmers. Within farmer budget viz. T_1 to T_4, T_4 provided the highest benefit with benefit-cost ratios of 8.79 and 8.61 in rice and central zones respectively (table 9) as compared to 8.13 and 7.41 respectively with farmer ratio (T_1) of fertilizer.

4. CONCLUSIONS

Grain yield data of field studies conducted during 2015-16 to 2017-18 in rice and central zone of Punjab showed that the highest yields were obtained with the application of recommended dose nitrogen, phosphorus and potassium. However, in perspective of present farmers' fertilizer budget, T_3 and T_4 provided the most economic returns. Out of 60 sites, 48 sites produced higher wheat yield at NP ratio 1.7:1. However, most of the sites indicated no significant difference between the results of T_3 (NP ratio 2:1) and T_4 (NP ratio 1.7:1) which indicates that both are the most economical rates of nitrogen and phosphorus for achieving higher yields.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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