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Yield and soil status disparity under rice-wheat cropping system: A 40 years Journey

Mitali Kumari Sah[1], Abhisek Shrestha[2], Shree Prasad Vista[3], Bisheswar Prasad Yadav[1]

[1]Directorate of Agriculture Research, Bara, Madhesh Province, Nepal
[2]College of Natural Resource Management, Agriculture and Forestry University, Bardibas, Nepal
[3]National Soil Science Research Centre, Khumaltar, Lalitpur, Nepal

Abstract

Long-term soil fertility experiment is valuable for evaluating the effects of continuous cropping on the capacity of a soil to sustain nutrient supply and the productivity. Thus, experiment was conducted to know the impact of different dose and source of fertilizers on crop yields under rice-wheat system in Directorate of Agricultural Research (DoAR), Bara. The experiment was carried out in Randomized Complete Block Design (RCBD) with 12 treatment and three replication from 1991 to till date. In this study, we used the latest seven years data viz. 2015. 2016. 2017, 2018, 2019, 2020 and 2021 for evaluating the yield and yield attributes of rice. The result showed that 50%N +FYM treated plot fb 100:30:30 NPK provided stable yield 3670-3835 kg/ha in rice and 2505-2694 kg/ha in wheat. However, inherent soil nutrient capacity still supporting more than 1999±550 kg/ha yield without any fertilizer application. The use of NPK plot had higher yield in decreaing trend and decreasing soil status. The pH was highly reduced in other treatment to average 5.4 but remain slightly decline in control from initial. The organic matter , N,P, and K was constantly high in FYM treated plot but notice declined in other plot So, this concluded that use of organic matters with reduce N could provide stable and higher yield and enhance soil status over long period of time.

Key Words: *Fertilizer, Nutrient, Rice, Soil-Fertility, Yield*

Introduction

Rice and wheat are the most important stable food crops of Nepal and mostly grown in Terai region. The production and productivity of these crops is comparatively less than neighboring country like India and China (MoALD, 2021), but the production has increased markedly with the introduction of modern technologies based on chemical fertilizer application and organic amendment (S. et al., 2001). Continuous cropping pattern removes the huge nutrient from the soil with harvested grain and straw that causes the depletion of soil fertility (Haque et al., 2019; Nishida, 2016; Rawal et al., 2017; Talpur et al., n.d.) . Several evidences showed intensive cultivation leads to decrease of soil organic carbon and soil fertility continuously (Haryuni et al., 2020), through the process of leaching, erosion and intensifying global warming. These causes farmers to focus for adding more inputs to obtain the same yields (De Datta & Gomez, 1975). In other hand, non-judicious use of chemical fertilizers causes the environment effect and finally causes deterioration of physical, chemical and biological component of soil fertility (Dong et al., 2012). Soil fertility is important natural input cost for sustainable and stable yield (Regmi et al., 2003).

In Nepal, the productivity decline due to lack of application of optimum NPK fertilizer inputs due to unavailability in market at the time of application and unaware of management practices (Rawal et al., 2017). Deficient in macro and micro-nutrient are the important factor causing the yield loss this days (S. et al., 2001; Talpur et al., n.d.; Yang et al., 2020). So, sole dependent on chemical fertilizer could cause long term harmful to both soil and human health and suffer from decline in yield and unstable and finally food hunger. Sustainable management and fertility improvement can be done through organic amendment and stubble incorporation (Gao et al., 2023; Yang et al., 2020). These added organic matter in soil act as a very reactive and ubiquitous soil quality indicators that influence the productivity and physical well-being of soils (Diacono & Montemurro, 2010).

Long term soil fertility experiment (LTFT) are valuable for evaluating the impact of continuous cropping on the capacity of a system to sustain nutrient supply and productivity. Reports from different LTFT conducted in Nepal revealed that organic amended plot provides the stable yield over year and also cut off half nitrogen in preceding crop wheat (Shrestha 2021), cause of wheat yield decline due to K deficiency in both rice-wheat and stable yield in NPK and FYM used (Rawal et al., 2017).

In the present study, the experiment of LTFT of rice-wheat system conducted over 4 years in DoAR, Parwanipur, Madhesh Province, Nepal to study the yield and yield attributes response to different fertilizer used.

Materials and Methods

Long-term experiment is valuable for evaluating the effects of continuous cropping on the capacity of a system to sustain nutrient supply and the productivity. This experiment was started in 1980/81 to evaluate the effects of organic manure and inorganic fertilizers on crop yields and to study the effects of N with or without P and K in the long run under rice-wheat system. The experiment was carried out in Randomized Complete Block Design (RCBD) with 12 treatment (Table 1 and 2) with 3 replication in DoAR, Parwanipur, Madhesh Province, Nepal over 2018-2021. Individual plot was allocated 24 $m^{2.}$ Fertilizer was applied as per the treatment. All P and K and ½ N was applied in basal dose while two split of remaining N was applied as Top dress. Swarna Sub-1 varieties has been used and two seedling were transplanted in 20X 20 cm spacing. The transplantation of rice wass done in 15-30 July of each year and wheat sown at october 15-20. Gautam varieties of wheat was used. Inter-cultural operation was conducted as required. Yield and yield attributes were observed at the time of harvesting. Yield was adjusted based on moisture percent in grain as formula as (Mulvaney & Devkota, 2020)

$$\text{Adjusted Yield (Kg/ha)} = \frac{\text{Yield at Harvested Moisture} \times (100\text{-M\% at harvest}) \ldots..}{(100\text{-standard M\%})}$$

Harvested Index was calculated as (Amanullah & Inamullah, 2016)

$$\text{HI} = \frac{\text{Economic Yield (Kg/ha)} \times 100}{\text{Biological Yield (kg/ha)}}$$

Sterility (Mitsuya et al., 2019)

$$\text{Sterility} = \frac{\text{No of unfilled grain} \times 100}{\text{Total grain}}$$

Statistical analysis was done through Genstat ver. 2015, and ranking of mean separation done by using Duncan Multiple Range Test (DMRT). Statistical significance for all analyses was evaluated at $P<0.05$ unless otherwise stated.

Table 1. Treatments of long-term soil fertility experiment under rice-wheat system 2018-2021

Treatments	Rice ($N:P_2O_5:K_2O$ kg ha^{-1})	Treatments	Rice ($N:P_2O_5:K_2O$ kg ha^{-1})
T_1	0:0:0	T_7	**50:0:0**
T_2	100:0:0	T_8	**50:20:0**
T_3	100:30:0	T_9	**FYM @ 10 t ha^{-1}**
T_4	100:0:30	T_{10}	**100:30:30 + 25 kg $ZnSO_4$ ha^{-1}**
T_5	100:30:30	T_{11}	**50:0:0 + FYM 10 t ha^{-1}**
T_6	**100:0:30**	**T_{12}**	**50:0:0 + Chopped straw 10 t ha^{-1}**

Table 2. Treatments of long-term soil fertility experiment under rice-wheat system 2018-2021

Treatments	Wheat ($N:P_2O_5:K_2O$ kg ha^{-1})	Treatments	Wheat ($N:P_2O_5:K_2O$ kg ha^{-1})
T_1	0:0:0	**T_7**	50:0:0
T_2	100:0:0	**T_8**	50:20:0
T_3	100:30:0	**T_9**	FYM 10 t/ha
T_4	100:0:30	**T_{10}**	100:30:30
T_5	100:30:30	**T_{11}**	100:30:30
T_6	100:30:30	**T_{12}**	100:30:30

Result and Discussion

Gami et al 2000 reported that there was significant difference in yield of rice at 1981-2000 interval and Shrestha et al., 2015 also showed the same. The result from 2015-2021 of consecutive year revealed that use of fertilizer especially N play great role in yield. With the increase of N as compared to control plot, yield has doubled from 1980 to 3089 kg/ha. With decrease in N, yield has declined upto 33 %. Interestingly, plot treated with 50 N kg/ha with FYm 10t/ha had higher yield 3630-3835 kg/ha which can reduces the use of chemical fertilizer in future days. However use of complete NPK fertilizer had although maintained their yield at par but, it showed the decreasing trend in yield.

Table 3. Rice yield over 40 years at different time interval

Treatment	Rice Yield (Kg/ha)		
	1981-2000	2000 to 2014	2015-2021
0:0:0	2540 c	1927.7±109.5 h	1980±424.8 g
100:0:0	3550 ab	3058.1±119.7 def	3089±882.8de
100:30:0	3610 ab	3330.4±10.5 bcd	3359±929.2 bcd
100:0:30	3700 ab	3128.8±106.5 cdef	3236±959 cd
100:30:30	3985 a	3571.2±88.6 abc	3302±846.4 bcd
100:0:0	3770 ab	3494.3±123.7 abcd	3778±864.9 a
50:0:0	3085 bc	2527.6±92.4 g	2671±674.4 f
50:20:0	3515 ab	2746±100.0 fg	2723±730 ef
FYM 10 t/ha	3280 ab	2808.7±109.5 efg	3207±877.4cd
100:30:30+25 Kg $ZnSO_4$	3855 a	3706.2±103.8 ab	3616±909.5 abc
50:0:0 +FYM 10t/ha	3670 ab	3835.2±101.6 a	3691±869.4 ab
50:0:0 +10t/ha chopped straw	3630 ab	3276.6±110.9 bcde	3064±812.9 def
P value	<0.001	<0.001	<0.001
HSD value	NA	497.1	385.2
CV (%)	12	21.2	7.2
	Gami et al., 2000	Shrestha et al., 2015	

Table 4. Wheat Yield over 40 years at time interval

Treatment	Wheat Yield (Kg/ha)		
	1981-2000	2000 to 2014	2015-2021
0:0:0	1025	577.2±28.8 e	526±184.6
100:0:0	2030	944.1±66.4 de	826±331.1
100:30:0	2055	1614.6±112.3 b	1299±882.0
100:0:30	2290	1449.6±70.8 bc	1188±788.7
100:30:30	2420	2454.9±107.8 a	2448±943.2
100:30:30	2430	2258.8±114.5 a	2526±980.9
50:0:0	1705	1128.4±58.1 cd	1004±527.0
50:20:0	1905	1358.7±88.3	1629±680.6
FYM 10 t/ha	1435	1203.3±55.6 bcd	924±335.8
100:30:30	2505	2398.8±126.9 a	2634±944.9
100:30:30	2465	2533.8±113.1 a	2876±725.7
100:30:30	2570	2478.7±121.5 a	2740±711.3
P value	<0.001	<0.001	<0.001
HSD value	NA	434.9	385.2
CV (%)	6.5	29.2	7.2
	Gami et al., 2000	Shrestha et al., 2015	

At the time of 1981-2000, use of complete fertilizer at recommended dose showed highest yield, and N and P was found important nutrient for enhancing yield of wheat. With the increment of N, it had double yield and with decline, it had reduced yield by almost 25%. FYM used in wheat had no significant impact over long period. The plot with no fertilizer had decline yield by more than 50 % over 40 years period. It means, inherent capacity of soil can now only support for 500 to 600 kg/ha yield of wheat and may decline in coming days. Use of fertilizer in currently doesn't mean to support the yields of crop but the practice made in previous crops. The appropriate use of chemical fertilizer had enhanced wheat yield over 40 years regardless of previous management practices. Shrestha et al., 2015 had also reported the similar cases in the experiments of 2000 to 2014.

Considering the cropping pattern and management practice in consecutive crop and year, over seven consecutive year (2015-2021) stated that no NPK plot (3032 kg/ha) provided very least total yield, and with increase of N only had increased yield by 51% and in addition of P, K, increased yield by 22%. In the same, use of complete fertilizer enhanced by 3 times as compared to control and 40 % above over +NP, +NK plot. Use of micro-nutrient over completed had higher yield over long period of time, in mean time, 50 N+10t/ha FYM (9444 kg/ha) had highest yield over these period. The application of P,K in one crop had been used for consecutive crop while in term of N, had been used in same crop. 10t/ha chopped straw+50kg N/ha followed by complete NPK had significant higher yield and at par with 50 N+10t/ha FYM treated plot. Gami et al., 2000 also reported that NPK+Zn fb NPK, 50N kg/ha+10t/ha FYM fb NPK, 100N fb NPK had significant yield over 20 years. The application of nutrient in one crop had influence over other and accumulative impact. Shrestha et al., 2015, had same concern over 14 years of experiment.

Table 5. Total cereal yield (equivalent to rice) in Kg/ha under different fertilizer application during 2015-2021

Treatment		Total Yield		
Rice	Wheat	1981-2000	2000-2014	2015-2021
0:00:00	0:00:00	3565	3082.1	3032 e
100:00:00	100:00:00	5580	4946.3	4742 d
100:30:00	100:30:00	5665	6559.6	5956 c
100:00:30	100:00:30	5990	6028	5611 cd
100:30:30	100:30:30	6405	8481	7155 b
100:00:00	100:30:30	6200	8011.9	8829 a
50:00:00	50:00:00	4790	4784.4	4679 d
50:20:00	50:20:00	5420	5463.4	5882 c
FYM 10 t/ha	FYM 10 t/ha	4715	5215.3	5056 cd
100:30:30+25 Kg ZnSO4	100:30:30	6360	8503.8	8885 a
50:0:0 +FYM 10t/ha	100:30:30	6135	8902.8	9444 a
50:0:0 +10t/ha chopped straw	100:30:30	6200	8234	8544 a
P value	P value			<0.001
HSD value	HSD value			326.3
CV (%)	CV (%)			8.7

Table 6. Total C, N, P and K of soils during 1998-1999

Treatment	pH			Total N (g Kg^{-1})			Total P (mg/kg)			Total K (mg/kg)		
	1998	2019		1998	2019					1998	2019	
		After Rice harvest	After wheat harvest		After Rice harvest	After wheat harvest	1998	After Rice harvest	After wheat harvest		After Rice harvest	After wheat harvest
Control	7.1	5.9	6.6	0.68	0.82	0.67	5	11.2	7.14	220	48.55	40.6
NPK	6.7	5.9	6.1	0.75	0.87	0.74	10	31.14	23.93	220	44.59	36.67
FYM	7.3	5.9	7	1.11	1.05	0.85	17	61.1	71.4	220	56.48	56.03
50 Kg N+10t FYM	6.8	5.6	6.3	0.94	0.99	0.94	17	47.3	48.9	210	56.48	44.59
50:0:0 +10t/ha chopped straw	6.5	5.9	6.1	0.86	0.78	0.77	8	14.4	48.5	230	48.5	48.5

Table 7. Soil status over different period under different fertilizer application

Rice	P (mg/kg)	OM%	K	N	pH	Wheat	N%	P	OM	K	pH
0:00:00	11.2 f	1.52 bc	48.55	0.082 bc	5.9	0:00:00	0.067 b	7.14 c	0.969 b	40.63 abc	6.6 ab
100:00:00	10.3 f	1.06 c	40.63	0.069 c	5.6	100:00:00	0.069 b	8.43 c	1.041 b	38.65 abc	5.7 e
100:30:00	31.14 c	1.50 bc	44.59	0.082 bc	5.9	100:30:00	0.070 ab	23.93 bc	1.070 ab	36.67 bc	6.1 bcd
100:00:30	11.32 f	1.20 c	46.57	0.079 c	5.6	100:00:30	0.070 ab	8.31 c	1.079 ab	52.51 a	6.1 bcd
100:30:30	21.6 cde	1.20 bc	40.63	0.087 bc	5.8	100:30:30	0.074 ab	21.53 bc	1.224 ab	50.53 ab	6.0 cde
100:00:00	13.6 ef	1.66 c	48.55	0.077 c	5.6	100:30:30	0.066 b	12.28 bc	0.934 b	42.61 abc	5.9 de
50:00:00	9.39 f	1.40 c	46.57	0.079 c	5.6	50:00:00	0.072 ab	10.24 c	1.155 ab	46.57 abc	6.3 bcd
50:20:00	19.01 def	1.60 bc	54.50	0.082 bc	6.4	50:20:00	0.078 ab	19.61 bc	1.365 ab	34.69 c	6.5 bc
FYM 10 t/ha	61.1 a	2.29 a	56.48	0.105 a	5.9	FYM 10 t/ha	0.085 ab	71.14 a	1.609 ab	50.53 ab	7.0 a
100[1]	25.7 cd	1.29 c	56.48	0.076 c	6.2	100:30:30	0.074 ab	19.13 bc	1.230 ab	34.69 c	6.2 bcd
50[2]	47.3 b	2.09 ab	56.48	0.099 ab	5.6	100:30:30	0.094 a	48.92 abc	1.897 a	44.59 abc	6.3 bcd
50[3]	14.4 ef	1.35 c	48.55	0.078 c	5.9	100:30:30	0.077 ab	53.96 ab	1.314 ab	48.55 abc	6.1 cde
P value	<0.001	<0.001	Ns	0.001	Ns	P value	Ns	0.02	Ns	0.04	<0.001
HSD value	9.16	0.56	19.4	0.016	0.87	HSD value	0.021	37.4	0.738	13.09	0.41
CV (%)	23.5	21.8	23.4	11.6	8.7	CV (%)	16.9	86.1	35.1	17.8	3.9

1: 00:30:30+25 Kg ZnSO4; 2: 50:0:0 +FYM 10t/ha; 3: 50:0:0 +10t/ha chopped straw

At initial stage, the soil pH condition was nearly neutral but after regular application of NPK and FYM in Rice has declined soil pH to 5.6 but it has been recovered to initials after wheat cultivation. FYM treated plot maintained the soil pH over 40 year at neutral state, other plots had moved to acidic condition. Similar result was demonstrated by (Rai & Khadka, 2014). The total nitrogen in soil was ranged from 0.68- 1.11 g Kg^{-1} where least in control, moderate in NPK, 50N+ FYM and 50N+ chopped straw plot and highest in FYM treated plot in 1998 but increase of N was immediately after rice harvest but decline after wheat in all context. Minimum decline was found in

control plot. The total P was found higher in plot where FYM was added continuously followed by 50N+ FYM and used of NPK fertilizer plot while control and 50N+ chopped straw plot with least total P. The decline of Total K was very rapid over 40 years. FYM treated plot had slow remove of K from soil and 50N+ chopped straw plot, however there was decline in other plot. Similar report in Tarahara by (Rai & Khadka, 2014).

Variation of yield over year

The yield was highly varied with year. There was fluctuation yield may due to climate factor like rainfall and temperature, and other-side management practice of researcher as change with time. Similar case was observed in other context of RARS farm (Rai & Khadka, 2014; Shrestha et al., 2015)

Conclusion

The rice-wheat is common cropping pattern of Nepal. The nutrient management become more challenging to attain higher yield due to unavailability of fertilizer at planting time and requirement bulk organic matter. Soil condition is decline in another part. This long term experiment concluded that use of 50% N + 10t FYM in rice fb 100:30:30 NPK/ha in wheat could balance both yield and soil status for long term and sustainable farming system. Use of balanced NPK can be used for quick response to gain yield but long turn it has decline trend in yield and degrade soil status. Regular use of FYM could provide stable yield but optimum yield could be harvested. Reduce use of high chemical fertilizer with use of organic fertilizer could be solution for optimum and stable production over climate change scenario.

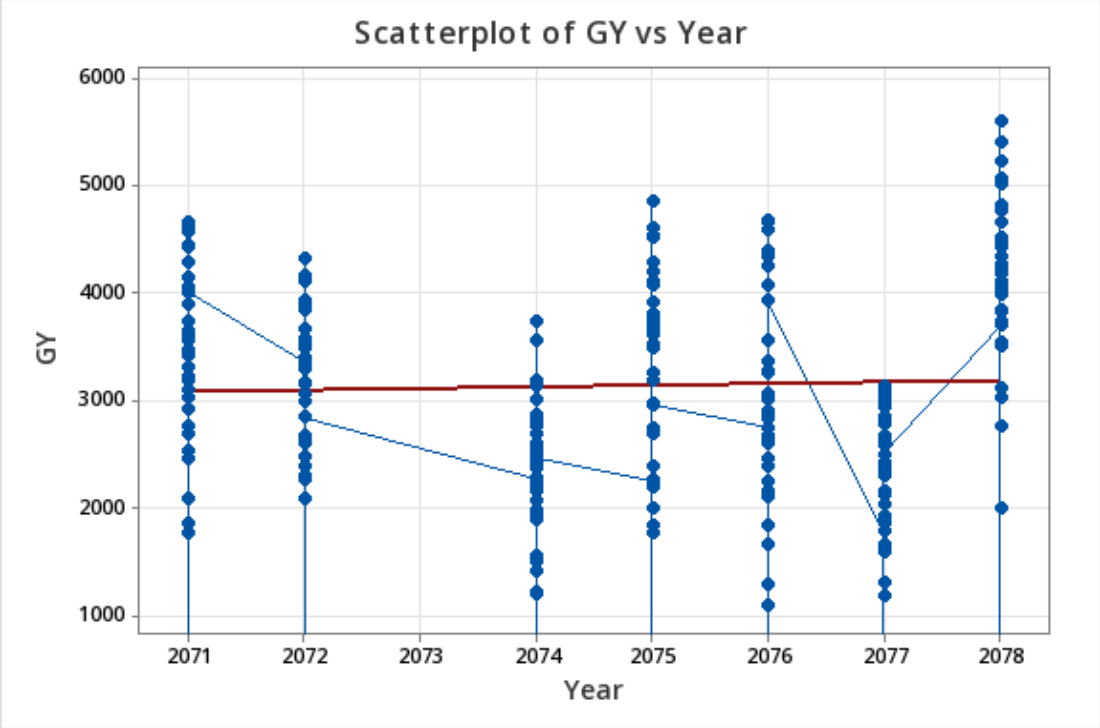

Figure 1. Variation of rice yield during different year

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