The integrated application of organic and inorganic fertilizers enhanced soil fertility under wheat-mungbean cropping system

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Abstract

Integrated application of organic and inorganic fertilizers enhances soil fertility to increase soil nitrogen, phosphorus and potassium concentration. The aim of this experiment was to investigate the combine effect of manures and mineral fertilizer on soil NPK status under wheat Mung bean cropping system. The research was conducted at Livestock Research and Development Station Surezai, Peshawar in two years filed trials in 2010-11 and 2011-12 in randomized complete block design with four replications. In this experiment three levels of poultry manure (2, 4 and 6 t ha^{-1}) three levels of farmyard manure (2, 4 and 6 t ha^{-1}) and two levels of nitrogen (60 and 90 kg ha^{-1}) along with control were applied to wheat crop. Mungbean was cultivated on the same plots after harvest of wheat without application of any fertilizers. Soil analysis for % nitrogen, phosphorus and potassium was done before and after the harvest of each crop. Poultry manure, farmyard manure and nitrogen significantly affected soil NPK content. The results showed that organic manures and inorganic fertilizers in combination used soil % nitrogen from (0.04 %) to (0.076), phosphorus from (6.0 mg kg^{-1}) to (10 mg kg^{-1}) and potassium from (75 mg kg^{-1}) to (101.68 mg kg^{-1}).

***Key words*:** Inorganic fertilizer, organic fertilizers, cereals, fertility and sustainable agriculture

Introduction

A combined dose of manures and mineral fertilizers provide adequate crop nutrition and also maintains soil fertility in terms of nutrients availability (Wicaksana, 2023). In agriculture manures are organic materials being used as a fertilizer for improving crop nutrition (Das, 2023). Manures improve soil health as they contain a diverse range of minerals which are taken by plants for their optimum nutrition (Baiyeri and Olajide, 2023). An abundant quantity of major and essential plant nutrients like nitrogen, phosphorus, and potassium and many other micro nutrients are fulfilled by manure (Saharan *et al*., 2023). Manures can also improve chemical composition of the soil. By applying manures the bulk density of soil decreases which increases organic matter and available water content (Özbolat *et al*., 2023). Manures help to improve yield of a variety of major crops *e.g.* cotton, sweet maize and wheat (Shah *et al*., 2023).

The need of organic sources which are effective in enhancing soil fertility and productivity is increased as the use of commercial fertilizers leads to many health and environmental hazards (Valle- García *et al*., 2023). Integrated management of mineral fertilizers and organic wastes can be considered as an important plan for sustainable crop production (Brichi *et al*., 2023). These strategies not only improve the performance of chemical fertilizers along with their minimal use in crop production besides it can also increase crop yield and can help to improve available major and minor soil nutrients (Manjesh *et al*., 2022). The amount of phosphorus in soil can be increased if organic and inorganic fertilizers are mixed and applied (Chen *et al*., 2023).

Residual effect of manures increases nutrient use efficiency in cereals. Manure as fertilizers adds more nutrients to soil and is more effective as compared to commercial fertilizer application (Yu, 2023). Soil NPK content can be increased and soil pH can be reduced with the application of organic fertilizers as compared to the use of mineral fertilizer which only maintains the soil NPK status (Xu *et al*., 2023). Higher yield in various crops can be achieved if manure and commercial fertilizers are used together (Jamal *et al*., 2023). The integrated application of manures and mineral fertilizers enhances long term productivity of soil in wheat cropping system (Zhang *et al*., 2023)

The recovery of mineral nitrogen from various manures and minerals shows that poultry manures recovers nitrogen up to 82% compared to mineral fertilizers (up to 69 %) and from farm yard manure it is up to 25% (Banik *et al*., 2023). This is due to the fact that nitrogen in poultry manure mineralizes at a faster rate as compared to cattle manure and other fertilizers. When organic manures and commercial fertilizers are applied and crop is harvested the residual effects of these fertilizers increases soil Carbon and crop yield (Bidzakin *et al*., 2023).

The objectives of the present experiment were to study the effect of FYM, Poultry manure and nitrogenous fertilizer on soil NPK status and also to know the optimum levels of fertilizer concentration for enhancing soil NPK.

Materials and Methods

Experimental Site: The experiment was conducted at Livestock Research and Development Station Surezai Peshawar. The experimental site is situated at South East of Peshawar city. It is situated at 34^0 N and 71.33^0 E with an altitude of 490 m above sea level in Khyber Pakhtunkhwa, Pakistan. Experimental site receives less than 350 mm annual rainfall and the climate of the site subtropical continental with worm to hot. Experimental site have fine silty with mixed clay loam soil. The soil pH is ranging from 7.7-8.0. The soil is very poor in macro nutrients like NPK and contains less than one percent organic matter.

Experimental treatments

Following organic and inorganic fertilizers were used

1. Poultry manure (PM)
   i. 2 t ha^{-1}
   ii. 4 t ha^{-1}
   iii. 6 t ha^{-1}
2. Farm yard manure (FYM)
   i. 2 t ha^{-1}
   ii. 4 t ha^{-1}
   iii. 6 t ha^{-1}

3. Nitrogen fertilizer kg ha^{-1}
   i. 60
   ii. 90

4. Control

Experimental Materials

The experiment was conducted using randomized complete block design (RCBD) with four replications. Organic and inorganic fertilizers were applied to wheat and mungbean on the same plots after the harvest of wheat with no fertilizers application. The plot size was 1.8×4m. Both wheat and mungbean crops were cultivated 30 cm apart in six rows. For mungbean thinning was done after completion of germination. Besides experimental treatments other inputs were implied uniformly which included hoeing, weeding and irrigation. Nitrogen was applied in the form of urea using two applications one at sowing and other after first irrigation.

Chemical Analysis of Soil, Farm Yard Manure and Poultry Manure

Soil analysis was done before the experiment and after the harvest of wheat and mungbean respectively during both years. Composite soil sample from various points were taken at the depth of 0-30 cm from the field. These samples were used for chemical analysis of NPK according to the standard procedures of analysis. Composite samples of poultry manure and farmyard manure were also collected for NPK analysis. After harvesting, each crop of wheat and mug bean soil samples were collected from a depth of 0-30 cm every year from three points in each treatment thoroughly mixed for composite sample. A sample of 500 g was dried and then sieved through 2 mm sieve. This sample was used for various chemical analysis of the soil and manures for NPK. The NPK analysis was done according to the procedure described by (Bremer, 1996, Mehlich, 1984 and ISO, 1998).

Statistical analysis

Data collected during experiment was analyzed according to Randomized Complete Block design and upon obtaining significant F-value, least significant difference (LSD) test was employed (Steel and Torrie, 1980).

Table 01. Nitrogen, phosphorus and potash content of soil and organic sources analysis for before the experiment

Source	% N	P mg kg^{-1}	K mg kg^{-1}
Soil	0.04	6.0	75
Poultry manure	2.80	2.84	2.30
Farm yard manure	1.08	0.20	0.45

Table 02: Treatment combination of farmyard manure, poultry manure and nitrogen

Treatments	PM t ha^{-1}	FYM t ha^{-1}	N Kg ha^{-1}
T1	0	0	0
T2	2	2	60
T3	2	4	90
T4	2	6	60
T5	2	2	90
T6	2	4	60
T7	2	6	90
T8	4	2	60
T9	4	4	90
T10	4	6	60
T11	4	2	90
T12	4	4	60
T13	4	6	90
T14	6	2	60
T15	6	4	90
T16	6	6	60
T17	6	2	90
T18	6	4	60
T19	6	6	90

Results and Discussion

Soil N content (%)

The data regarding soil N content after each season harvest as affected by organic and inorganic fertilizers is presented (Table 03). Season (S), PM×FYM, FYM×N and control vs rest significantly affected % N in soil after each season harvest of wheat and mungbean.

Mean values for soil N after harvest of wheat in first year (2010-11) revealed that maximum soil N (0.096 %) was recorded in treatments in which PM and FYM were integrated in a ratio of six tons each with 90 kg nitrogen ha^{-1} as compared to control plots (.04%). Similarly mean values for soil N after harvest of mungbean in first year revealed that maximum soil N (0.096 %) was recorded in treatments in which PM and FYM were integrated in a ratio of six tons each with 90 kg nitrogen ha^{-1} as compared to control plots (.04%) while minimum N was noted in control treatments without fertilizer application.

Mean values for soil N after harvest of wheat in second year (2011-12) revealed that maximum soil N (0.096 %) recorded at PM and FYM was integrated in a ratio of six tons each with 90 kg nitrogen ha^{-1} compared to control plots (.04%). Similarly mean values for soil N after harvest of mungbean in second year revealed that maximum soil N (0.096 %) was obtained at PM and FYM was integrated in a ratio of six tons each with 90 kg nitrogen ha^{-1} as compared to control plots (.04%) N was recorded.

These results indicate that soil nitrogen content increased over the seasons after the application of organic and inorganic fertilizers. High nitrogen content in soil in last season is because of residual effect of N from the organic sources applied to the previous wheat crop. Same results have been reported by Ghosh *et al*. (2004) who investigated the comparative efficiency of cow manure, poultry manure, phosphocompost, and fertilizer-NPK on three cropping systems in semi-arid tropical vertisols for crop yields and system performance and Korsaeth *et al*. (2002) who assessed temporal variations in N mineralization and immobilization during plant material degradation: implications for plant N supply and nitrogen losses. They both

also found that following the application of organic and inorganic fertilizers, the nitrogen content of the soil rose over the seasons which indicates the significance of integrated application of organic and inorganic fertilizer for enhanced yield and productivity of important agricultural crops.

Table 03. Soil N (%) as affected by organic and inorganic fertilizers

Sources			Soil N content (%)			
PM (t ha^{-1})	FYM (t ha^{-1})	N (kg ha^{-1})	After Wheat 2011	After Mungbean 2011	After Wheat 2012	After Mungbean 2012
0	0	0	0.040	0.040	0.04	0.045
2	2	60	0.050	0.050	0.06	0.077
2	4	90	0.056	0.060	0.08	0.068
2	6	60	0.060	0.070	0.07	0.070
2	2	90	0.058	0.048	0.08	0.082
2	4	60	0.068	0.071	0.07	0.072
2	6	90	0.070	0.068	0.07	0.080
4	2	60	0.072	0.070	0.09	0.065
4	4	90	0.075	0.080	0.06	0.075
4	6	60	0.078	0.073	0.07	0.065
4	2	90	0.080	0.081	0.08	0.058
4	4	60	0.079	0.079	0.07	0.078
4	6	90	0.082	0.078	0.07	0.090
6	2	60	0.082	0.075	0.08	0.082
6	4	90	0.088	0.090	0.08	0.080
6	6	60	0.090	0.091	0.08	0.077
6	2	90	0.093	0.091	0.09	0.085
6	4	60	0.091	0.085	0.09	0.092
6	6	90	0.093	0.094	0.09	0.098
		Mean	0.074	0.073	0.074	0.076

Soil P content (mg kg^{-1})

Season (S), poultry manure (PM), farm yard manure (FYM), PM×N, FYM×N and control vs rest significantly affected soil P after each harvest of wheat and mungbean in two consecutive years (2010-11; 2011-12) (Table 04). Mean values for soil P after harvest of wheat in first year (2010-11) revealed that maximum soil P (9.44 mg kg^{-1}) was recorded where PM and FYM were integrated in a ratio of six tons each with 90 kg nitrogen ha^{-1} compared to control plots (6.50 mg kg^{-1}). Similarly mean values for soil P after harvest of mungbean in first year revealed that maximum soil P (10.30 mg kg^{-1}) was recorded where PM and FYM were integrated in a ratio of

six tons each with 90 kg nitrogen ha^{-1} as compared to control plots (7.0 mg kg^{-1}) while minimum P (7.30 mg kg^{-1}) was recorded at the rate of 2 t PM $ha^{-1,}$ 2 t FYMha^{-1} and 60 kg N ha^{-1}.

Mean values for soil P after harvest of wheat in second year (2011-12) revealed that maximum soil P (11.9 mg kg^{-1}) was recorded in plots which received combined dose of 6 t poultry manure $ha^{-1,}$ 6 t farm yard manure ha^{-1} and 90 kg N ha^{-1} as compared to control plots (6.0 mg kg^{-1}) while minimum P (7.0) was recorded in plots which received combined dose of 2 t poultry manure $ha^{-1,}$ 2 t farm yard manure ha^{-1} and 60 kg N ha^{-1} after harvest of wheat in second year (2011-12). Similarly mean values for soil P after harvest of mungbean in second year revealed that maximum soil P (13.0 mg kg^{-1}) was obtained where PM and FYM were integrated in a ratio of six tons each with 90 kg nitrogen ha^{-1} as compared to control plots (8.0 mg kg^{-1}) while minimum P (8.10mg kg^{-1}) was recorded in plots which received combined dose of 2 t poultry manure $ha^{-1,}$ 2 t farm yard manure ha^{-1} and 60 kg N ha^{-1} .

Soil P content increased over the seasons after the application of organic and inorganic fertilizers. High P content in soil in last season may be due to the residual effect of P from the organic sources applied to the previous wheat crop. Same results have been reported by Nath *et al*. (2023) who evaluated improved soil quality in rice ecology by using pulse crops and organic amendments in cropping systems and the evidence from a 16-year long-term experiment indicated that by including pulses in cropping systems can improve soil quality in cereal-dominant agroecologies over time.

Soil K content (mg kg^{-1})

Season (S), PM, PM×N, FYM×N, PM×FYM×N, control vs rest and S×control vs rest significantly affected K content in soil after each harvest of wheat and mungbean in two consecutive years (2010-11;2011-12) (Table 05).

Mean values for soil K after harvest of wheat in first year (2010-11) revealed that maximum soil K (105 mg kg^{-1}) was obtained where PM and FYM was integrated in a ratio of six tons each with 90 kg nitrogen ha^{-1} as compared to control plots (75 mg kg^{-1}) while minimum K (80 mg kg^{-1}) was obtained where PM and FYM was integrated in a ratio of six tons each with 90 kg nitrogen ha^{-1} after harvest of wheat in first year (2010-11). Similarly mean values for soil K after harvest of mungbean in first year revealed that maximum soil P (110 mg kg^{-1}) was obtained where PM and

FYM was integrated in a ratio of six tons each with 90 kg nitrogen ha^{-1} as compared to control plots (89 mg kg^{-1}).

Table 04: Soil P (mg kg^{-1}) as affected by organic and inorganic fertilizers

Sources			Soil P content (mg kg^{-1})			
PM (t ha^{-1})	FYM (t ha^{-1})	N (kg ha^{-1})	After wheat 2011	After Mungbean 2011	After Wheat 2012	After Mungbean 2012
0	0	0	6.50	7.00	6.00	8.00
2	2	60	7.20	7.30	7.00	8.10
2	4	90	8.00	7.50	8.00	9.60
2	6	60	7.50	8.00	7.30	10.00
2	2	90	8.50	7.90	8.00	11.00
2	4	60	9.00	8.20	7.50	8.90
2	6	90	9.00	8.60	7.00	12.00
4	2	60	9.20	8.92	8.00	11.30
4	4	90	8.20	9.00	10.0	8.80
4	6	60	8.60	9.35	9.00	10.00
4	2	90	8.30	9.10	8.60	10.10
4	4	60	8.00	8.88	8.90	10.20
4	6	90	9.10	9.20	10.0	10.00
6	2	60	8.90	9.40	9.90	9.90
6	4	90	9.80	10.00	10.0	8.70
6	6	60	9.90	9.98	10.0	9.60
6	2	90	10.00	9.93	8.90	10.40
6	4	60	8.50	10.25	11.2	11.70
6	6	90	8.70	10.30	11.9	13.00
		Mean	8.574	8.885	8.800	10.068

Soil K content after harvest of wheat in second year (2011-12) revealed that maximum soil K (110 mg kg^{-1}) was obtained where PM and FYM was integrated in a ratio of six tons each with 90 kg nitrogen ha^{-1} as compared to control plots (85 mg kg^{-1}). Similarly mean values for soil K after harvest of mungbean in second year revealed that maximum soil K (110 mg kg^{-1}) was obtained where poultry manure and FYM was integrated in a ratio of six tons each with 90 kg nitrogen ha^{-1} as compared to control plots (90 mg kg^{-1}). The present research has striking resemblance with

These results indicate that soil K content increased over the seasons after application of organic and inorganic fertilizers. High K content in soil in last season may be due to the residual effect of nitrogen from the organic sources applied to the

previous wheat crop. Same results have been reported by Kumari *et al*. (2023), they studied sulphur forms and maize production under long-term tillage and cropping regimes and discovered that organic and inorganic fertilizers, as well as conservation techniques, had a significant influence on K availability, yield, and K uptake by the maize crop.

Table 05: Soil K (mg kg^{-1}) as affected by organic and inorganic fertilizers

Sources			Soil K content (mg kg^{-1})			
PM (t ha^{-1})	FYM (t ha^{-1})	N (kg ha^{-1})	After wheat 2011	After Mungbean 2011	After Wheat 2012	After Mungbean 2012
0	0	0	75	89	85	90
2	2	60	80	105	99	92
2	4	90	85	100	89	95
2	6	60	83	92	98	94
2	2	90	88	100	88	98
2	4	60	90	95	102	100
2	6	90	98	100	101	107
4	2	60	95	100	107	110
4	4	90	93	100	100	98
4	6	60	100	95	103	105
4	2	90	100	92	102	110
4	4	60	110	90	110	107
4	6	90	105	98	99	100
6	2	60	100	94	108	109
6	4	90	98	110	109	115
6	6	60	110	98	108	110
6	2	90	110	105	100	95
6	4	60	100	107	101	97
6	6	90	105	110	110	100
		Mean	96.05	98.95	101.00	101.68

Recommendations

It is concluded from the present study that organic and inorganic fertilizers should be used in combinations to improve soil fertility. Mungbean should be included in crop rotation in order to improve soil fertility. The combined application of each six tons PM and FYM and 90 kg nitrogen ha^{-1} is recommended for higher yield in wheat and for increasing soil fertility.

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