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308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

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Integrated Plant Nutrient Management (IPNM) on Maize under Rainfed Condition

M.D. Dilshad[1], M.I. Lone[2], Ghulam Jilani[2], M. Azim Malik[2], M. Yousaf[2],
Rizwan Khalid[1] and Fakhra Shamim[2]
[1]Soil Fertility Survey and Soil Testing Institute, Rawalpindi, Pakistan
[2]PMAS Arid Agriculture University, Rawalpindi, Pakistan

Abstract: Integrated use of plant nutrients aim at combined use of inorganic and organic sources of plant nutrients to improve efficiency of applied nutrients, reduce environmental hazards and improve crop productivity. A field experiment was conducted at the Research Farm of Soil Science and SWC, Arid Agriculture University, Rawalpindi, Pakistan. It was laid out according to RCBD in split-plots with three replications. The sub-plot size was 6 m x 4 m (24 m^2). The wheat-maize cropping system was used to record data of two summer maize crops in under rainfed environment. There were nine treatments of integrated plant nutrient management practices. These included: control (without NPK fertilizer, FYM or biofertilizer); half of recommended NPK; full dose of recommended N-P_2O_5-K_2O (120-90-60 kg/ha); FYM @ 20 t/ha, FYM on N requirement basis + make-up dose of P/K fertilizer; ½ NPK + FYM @ 10 t/ha; ½ NPK + Biopower; ½ FYM + Biopower and ½ NPK + ½ FYM + Biopower. The significant increase in various yield attributes due to IPNM produced highest biological and grain yield of 8579 kg/ha and 3128 kg/ha in 2005; while these were recorded 8475 kg/ha and 3119 kg/ha respectively in 2006. Integrated plant nutrient treatments especially with Biopower improved NPK uptake over sole mineral/organic fertilizers. The economic analysis revealed that wheat-maize cropping system was profitable with integrated use of mineral, organic and/or biofertilizer Biopower under rainfed condition.

Key words: Plant nutrients, environmental hazards, crop productivity

INTRODUCTION

The integrated use of organic and inorganic fertilizers not only increase mutual efficiency but also help in the substitution of costly chemical fertilizers (Hussain and Ahmed, 2000; Ghosh and Sharma, 1999). Maize (*Zea mays* L.) is one of the most important cereal crops of the world used as food, feed and raw materials. Globally maize is grown on 140 million hectares. Out of which 96 m ha are in the developing world. It makes 68% of the total areas but only 46% of the world maize is produced there. Average yield of maize in the industrialized countries is 8 t/ha. The major crops of rainfed areas of Pakistan are wheat, maize, sorghum, millet and mungbean. The average maize yield in Pakistan is 1.86 t/ha. Still in rainfed areas of Pakistan, grain yield of maize is 54% lower than in irrigated areas (GOP, 2008). The Pothwar zone produces more than 80% of rainfed maize. The average is very low in spite of is great yield potential. Improvement in average yield per hectare can be obtained if soil fertility is maintained through the combined use of organic and inorganic fertilizers.

Considering the economic importance of maize crop as fodder and grain, this field experiment was conducted to study the effect of IPNM on yield components and yield of maize under rainfed conditions.

MATERIALS AND METHODS

A field experiment was conducted at the research farm of Arid Agriculture University, Rawalpindi, Pakistan to evaluate the effects of Integrated Plant Nutrient Management (IPNM) on yield and yield components of summer maize (*Zea mays* cv. Agaiti, 2002) during the Kharif seasons of 2005 and 2006. It was laid out according to RCBD in Split-plots having nine Integrated Plant Nutrient Management (IPNM) practices: control (No IPNM), ½ recommended doze of NPK, NPK, Farmer's application of FYM @ 20 t/ha, FYM (N equivalent with P make up dose, ½ NPK + biofertilizer Biopower, ½ FYM + Biopower, ½ NPK + ½ FYM, ½ NPK + ½ FYM + Biopower. All treatments were applied with three replications. The sub-plot size was 6 m x 4 m (24 m^2). Composite soil sample were collected from the experimental field from two depths (0-15 cm and 15-30 cm) before sowing. Soil samples were collected from each treatment from depth (0-15 cm) after the harvest of maize.

Chemical analysis: Soil samples were analyzed for various physical and chemical characteristics. Soil texture was determined by hydrometer method as described by Koehler *et al.* (1984); pH in soil water suspension (1:10) with pH meter by the method outlined

Corresponding Author: M.D. Dilshad, Soil Fertility Survey and Soil Testing Institute, Rawalpindi, Pakistan

Table 1: Physical and chemical properties of composite soil sample before start of experiment

Characteristics	Depth 0-15 cm	15-30 cm
Clay (%)	16.00	17.00
Silt (%)	39.00	40.00
Sand (%)	45.00	43.00
Soil texture	---------- Sandy loam ----------	
Soil pH	7.80	7.91
EC_e (dSm^{-1})	0.25	0.21
Bulk density (Mgm^{-3})	1.40	1.53
Soil moisture (g 100 g^{-1})	8.82	9.20
Total N (µg g^{-1})	152.00	154.00
Organic C (g100 g^{-1})	0.32	0.33
Available P (µg g^{-1})	3.45	3.55
Extractable K (µg g^{-1})	80.00	85.00
Zn (µg g^{-1})	0.34	0.33
Fe (µg g^{-1})	2.15	2.32
Mn (µg g^{-1})	1.33	1.33
Cu (µg g^{-1})	0.31	0.32
Soil series	------ Rawalpindi soil series -----	
Soil order	*Inceptisol*	
Parent material	Loess	

by Mc Lean (1984). Alkaline earth carbonate in soil was determined by using acid neutralization method as outlined by Richards (1954). Organic carbon was determined by the method given by Nelson and Sommers (1982). Total nitrogen was determined by Kjeldahl digestion method (AOAC, 1982). Available phosphorus was determined by Spectronic 601 (Milton Roy Co.) as described by Soltanpour and Schwab (1977). NH_4 acetate extractable potassium was determined by Flame photometer (PFP Jenway). The data for yield and yield components was recorded at physiological maturity. Leaf and grain samples from individual treatments were analyzed for total nitrogen by Kjeldahl digestion method; Phosphorus was determined by AB-DTPA extractable P method; Total K concentration was determined by flame photometer.

Economic and statistical analysis: Growth, yield and soil parameters were recorded and then analyzed statistically according to standard statistical procedures described by Sokal and Rohlf (1997). Data showing significant difference at $p \leq 0.05$ was put to comparison of treatments means by Duncan's (1961) multiple range test. All the data was processed using MSTAT software for statistical analysis. For economic analysis, after considering the cost of fertilizer N, P, K, farmyard manure and biofertilizer Biopower application, the incomes from seed yield were used for economic analysis (CIMMYT, 1988) using the formula:

Value Cost Ratio (VCR) = Value of increased yield obtained/ cost of mineral/organic/biological nutrient sources

Table 2: Effect of integrated plant nutrient management on plant height (cm) of maize

Treatments	Years 2005	2006
	---------- CS ----------	
T_1 Control	172.2^{C}	170.6^{D}
T_2 NPK (60-45-30) kg ha^{-1}	182.1^{B}	193.5^{C}
T_3 NPK (120-90-60) kg ha^{-1}	206.7^{A}	206.5^{AB}
T_4 Full FYM @ 20 t ha^{-1}	183.4^{B}	201.9^{BC}
T_5 FYM (N Eq + P make up)	189.1^{B}	203.8^{BC}
T_6 ½NPK + ½ FYM	208.3^{A}	207.1^{AB}
T_7 ½NPK + Biopower	185.9^{B}	197.4^{BC}
T_8 ½FYM + Biopower	187.9^{B}	198.8^{BC}
T_9 ½NPK + ½ FYM + Biopower	211.0^{A}	216.0^{A}
Analysis of variances		
P-Value	<0.001	<0.001
LSD	9.14	9.85
SE	3.05	3.28
CV (± %)	2.75	2.85

Data are average of three replications.

• Means followed by the same letter (s) are not significantly different ($P < 0.05$; DMR Test) to each other.

CS: Cropping System. Biofertilizer Biopower (seed inoculation at sowing). NPK @ (120-90-60) kg/ha. Farmyard Manure (FYM) @ 20 t/ha. FYM * (N equivalent + P make up doze)

RESULTS AND DISCUSSION

Plant height: Plant height is important parameter of yield in maize as usually taller plant bears more cobs and give more yield. Comparison of various treatment means in 2005 indicated that plant height increased significantly as compared to control (Table 2). The application of ½ NPK + ½ FYM + Biopower produced maximum plant height of 211.0 cm followed by 208.36 cm by treatment of ½ NPK + ½ FYM and 206.73 cm due to application of NPK which were statistically at par among each other. During 2006, the application of ½ NPK + ½ FYM + Biopower produced maximum plant height of 216.0 cm followed by 207.10 cm by treatment of ½ NPK + ½ FYM and 206.56 cm due to application of NPK which were statistically at par among each other. The plant height recorded in 2006 is better than plant height in 2005 due to IPNM. The treatment of ½ NPK + ½ FYM + Biopower produced maximum plant height in both years.

Biological yield: Biological yield represents total amount of above ground biomass accumulated by the plant. The data pertaining to the biological yield (kg/ha) of maize is given in Table 3. During first year (2005), ½ NPK + ½ FYM + Biopower (T_9) produced highest biological yield of 8579 kg/ha. It was followed 8292 kg/ha by treatment of ½ NPK + ½ FYM (T_6) with a significant difference between the two. Mineral fertilizers NPK produced 7933 kg/ha, which was significantly higher than all treatments except T_6 and T_9. FYM with P make up dose (T_5) and FYM @ 20 t/ha (T_4) gave biological yield of 7409 kg/ha

Table 3: Effect of integrated plant nutrient management on biological yield (kg/ha) of maize

Treatments	Years	
	2005	2006
	CS	
T_1 Control	3562^{I}	3290^{H}
T_2 NPK (60-45-30) kg ha^{-1}	5563^{H}	4191^{G}
T_3 NPK (120-90-60) kg ha^{-1}	7933^{C}	7884^{B}
T_4 Full FYM @ 20 t ha^{-1}	7147^{E}	6981^{D}
T_5 FYM (N Eq + P make up)	7409^{D}	7252^{C}
T_6 ½ NPK + ½ FYM	8292^{B}	8060^{B}
T_7 ½ NPK + Biopower	6214^{G}	6051^{F}
T_8 ½ FYM + Biopower	6543^{F}	6508^{E}
T_9 ½ NPK + ½ FYM + Biopower	8579^{A}	8475^{A}
Analysis of variances		
P-Value	<0.001	<0.001
LSD	51.19	236.2
SE	17.08	78.79
CV (± %)	0.43	2.09

and 7147 kg/ha respectively, which were statistically significant to each other. Both Biopower treatments with ½ NPK (T_7) and ½ FYM (T_8) produced biological yield 6214 kg/ha and 6543 kg/ha respectively, which were significantly different to each other.

During second year (2006), ½ NPK + ½ FYM + Biopower (T_9) produced highest biological yield of 8475 kg/ha. It was followed by 8060 kg/ha due to T_6 treatment with a significant difference. Mineral NPK fertilizers (T_3) produced 7884 kg/ha, which was significantly lower to both T_9 and T_6. FYM with P make up dose and FYM @ 20 t/ha gave biological yield of 7252 and 6981 kg/ha respectively, which were statistically significant to each other. Both Biopower treatments with ½ NPK and ½ FYM produced biological yield of 6051 and 6508 kg/ha respectively, which were significantly different to each other. The difference between highest and lowest biological yield was recorded as 5017 kg/ha and 5185 kg/ha in 2005 and 2006 respectively indicating substantial increase in biological yield due to integrated use of mineral and organic/biological nutrient sources. Biofertilizer Biopower in combination with organic and mineral fertilizers increase the microbial activity that in turn enhanced the rate of decomposition of organic matter and nutrient got available to plants for growth. The results are similar to Wu *et al*. (2005) who evaluated the effects biofertilizers on soil properties and the growth of *Zea mays* and reported not only increased the nutritional assimilation (total N, P and K) of plants, but also improved soil properties, such as organic matter content and total N in soil. However, biological yield produced in 2006 was lower than that produced in 2005. It might be due to the reason that there was lower rainfall during the maize growing season in 2006. Jadoon *et al*. (2004), Bhatti (2006), Khaliq *et al*. (2006) and Ahmad *et al*. (2008) also recorded better yield attributes of crops by integrated use of organic and mineral fertilizers.

Table 4: Effect of integrated plant nutrient management on grain yield (kg/ha) of maize

Treatments	Years	
	2005	2006
	CS	
T_1 Control	1310^{I}	1155^{G}
T_2 NPK (60-45-30) kg ha^{-1}	1920^{H}	1476^{F}
T_3 NPK (120-90-60) kg ha^{-1}	2878^{C}	2840^{B}
T_4 Full FYM @ 20 t ha^{-1}	2584^{E}	2446^{D}
T_5 FYM (N Eq + P make up)	2672^{D}	2570^{C}
T_6 ½ NPK + ½ FYM	3045^{B}	2878^{B}
T_7 ½ NPK + Biopower	2251^{G}	2172^{E}
T_8 ½ FYM + Biopower	2375^{F}	2372^{D}
T_9 ½ NPK + ½ FYM + Biopower	3128^{A}	3119^{A}
Analysis of variances		
P-Value	<0.001	<0.001
LSD	22.62	113.5
SE	7.545	37.87
CV (± %)	0.53	2.81

Grain yield: Data pertaining to the grain yield of maize crop is given in Table 4. During first year (2005), application of ½ NPK + ½ FYM + Biopower (T_9) produced highest grain yield of 3128 kg/ha. It was followed by treatment ½ NPK + ½ FYM (T_6) that produced 3045 kg/ha with a significant difference to preceding treatment. Mineral NPK fertilizers produced grain yield of 2878 kg/ha, which was significantly lower to both T_9 and T_6. The FYM with P make up dose (T_5) and FYM @ 20 t/ha (T_4) gave grain yield of 2672 kg/ha and 2584 kg/ha respectively, which were statistically significant to each other. Biofertlizer Biopower treatments with ½ NPK (T_7) and ½ FYM (T_8) produced grain yield of 2251 kg/ha and 2375 kg/ha respectively, which were significantly different to each other.

During second year (2006), ½ NPK+½ FYM+Biopower (T_9) produced maximum grain yield of 3119 kg/ha. It was followed by significantly lower grain yield of 2878 kg/ha by treatment T_6. Recommended dose of mineral fertilizers NPK produced grain yield of 2840 kg/ha, which was significantly lower than T_6. Application of FYM with P make up dose and FYM @ 20 t/ha produced grain yield of 2570 kg/ha and 2446 kg/ha respectively, which were statistically significant to each other. Biopower treatments with ½ FYM recorded a significant increase in grain yield (2372 kg/ha) over Biopower treatment with ½ NPK that produced grain yield of 2172 kg/ha. A significant increase in grain yield due to integrated nutrient management practices was observed in both years. Maximum grain yield was observed, when ½ NPK+½ FYM+ Biopower were applied. Biofertilizer Biopower in combination with organic and mineral fertilizers increased the microbial activity that might in turn enhance the rate of decomposition of organic matter and nutrients were available to plants for growth. Results of previous studies indicated that use of organic sources as FYM produced equivalent or increased plant biomass and grain yield of maize as application of inorganic fertilizers alone (Alam and Shah, 2003; Bakhtiar *et al*., 2002; Khanum *et al*., 2001).

Table 5: Effect of integrated plant nutrient management on NPK uptake (kg/ha) of maize

	Years					
	2005			2006		
Treatments	N	P	K	N	P	K
T_1 Control	38	8	58	27	8	53
T_2 NPK (60-45-30) kg ha^{-1}	70	12	106	48	13	80
T_3 NPK(120-90-60) kg ha^{-1}	138	42	244	148	40	256
T_4 Full FYM @ 20 t ha^{-1}	118	26	211	120	36	209
T_5 FYM (N eq + P make up)	125	29	195	128	40	221
T_6 ½NPK + ½ FYM	141	31	217	146	37	191
T_7 ½NPK + Biopower	90	25	136	89	26	135
T_8 ½ FYM + Biopower	99	25	151	101	27	148
T_9 ½NPK + ½ FYM + Biopower	143	48	228	156	46	220

The difference between highest and lowest grain yield was recorded as 1818 kg/ha and 1964 kg/ha in 2005 and in 2006 respectively, indicating substantial increase in biological yield due to integrated use of mineral and organic/biofertilizer nutrient sources. However, grain yield produced in 2006 was lower than that produced in 2005. Variation in grain yield may also be due to difference in rainfall amount and distribution and/or temperature variation during the growing season in first year and second year. Low moisture availability affects fertilizer use efficiency and yield components in rainfed areas Jadoon *et al*. (2004), Bhatti (2006), Khaliq *et al*. (2006) and Ahmad *et al*. (2008) also recorded better yield of crops by integrated use of organic and mineral fertilizers.

NPK uptake by maize: Data pertaining to the N, P and K uptake (kg/ha) of maize is given in Table 5. Integrated plant nutrient management practices in wheat-maize (CS_2) cropping system increased N, P and K uptake (kg/ha) by maize. During 2005, application of ½ NPK + ½ FYM + Biopower (T_9) recorded maximum N uptake of 143 kg/ha followed by N uptake of 138 kg/ha by recommended dose of NPK fertilizers (T_3). Maximum P uptake of 48 kg/ha was recorded in T_9 followed by P uptake of 42 kg/ha by mineral fertilizers (T_3). Maximum K uptake of 244 kg/ha was recorded by mineral fertilizers (T_3) followed by K uptake of 228 kg/ha in T_9. During 2006, application of ½ NPK + ½ FYM + Biopower (T_9) recorded maximum N uptake of 156 kg/ha followed by N uptake of 148 kg/ha by recommended dose of NPK fertilizers (T_3). Maximum P uptake of 46 kg/ha was recorded in T_9 followed by P uptake of 40 kg/ha by mineral fertilizers. Maximum K uptake of 256 kg/ha was recorded by mineral fertilizers (T_3) followed by K uptake of 220 kg/ha in T_9. The results showed that integrated use of organic and mineral fertilizers and/or biofertilizers showed better performance regarding grain yield of wheat. Integrated plant nutrient management had advantage over the sole application of mineral and organic and/ or biofertilizers. During 2005, application of ½ NPK + ½ FYM + Biopower (T_9) recorded 3.6 and 14.2% increase in uptake of N and P by maize over mineral fertililizer treatment (T_3) while during 2006, application of ½ NPK + ½ FYM + Biopower (T_9) recorded 5.4 and 15% increase in uptake of N and P by maize over mineral fertililizer treatment (T_3). Integrated plant nutrient treatment especially with Biopower improved NPK uptake over mineral fertilizers. This was due to the fact that Biopower contained four different species of N-fixing bacteria, which resulted into increased availability of nitrogen to the crop. Wu *et al*. (2005) indicated that half the amount of biofertilizer application had similar effects when compared with organic fertilizer or chemical fertilizer treatments. Microbial inoculum not only increased the nutritional assimilation (total N, P and K) of plants, but also improved soil properties. Combination of N fertilizer with EM also increased the concentrations of NPK in plants (Khaliq *et al*., 2006).

The economic analysis: The Value Cost Ratio (VCR) is the ratio between the value of the additional seed yield and the cost of the fertilizer. It is the rate of return of the money spent on fertilizer. If the VCR is greater than one, the fertilizer will be profitable. A VCR of 2 represents a 100% return on the money invested in fertilizer. At VCR lower than 2, farmer's margin of return becomes low.

Data regarding the VCR due to IPNM for maize is represented in Table 6. The VCR indicated that the IPNM showed profitable effect on maize in both years. These indicate that VCR due to IPNM is 1.91 in T_9 and 1.86 in T_6 while 1.89 in T_3. Better VCR in T_9 might be due in residual soil fertility. Similarly, VCR of 2.06 in T_9, 1.85 in T_6 while 2.04 in T_3 were estimated in 2006. It indicated better performance of integrated use of mineral and organic and/or biofertilizers. During 2005, highest VCR was recorded with treatment T_7 (½ NPK + Biopower), while lowest was recorded in control. It was followed by VCR recorded in T_9 (½ NPK + ½ FYM + Biopower) depicting the profitability of integrated use of inorganic and organic and/or biofertilizers for wheat production under rainfed condition. During 2006, highest VCR was recorded with treatment T_7 (½ NPK + Biopower), while lowest was recorded in control. It was followed by VCR

Table 6: Value cost ratio due to integrated plant nutrient management on seed yield of maize

Treatments	Years 2005	2006
	---------- CS_2 ----------	
T_1 Control	-	-
T_2 NPK (60-45-30) kg ha^{-1}	1.47	0.78
T_3 NPK (120-90-60) kg ha^{-1}	1.89	2.04
T_4 Full FYM @ 20 t ha^{-1}	1.23	1.24
T_5 FYM (N Eq + P make up)	1.27	1.32
T_6 ½ NPK + ½ FYM	1.86	1.85
T_7 ½ NPK + Biopower	2.17	2.34
T_8 ½ FYM + Biopower	1.97	2.25
T_9 ½ NPK + ½ FYM + Biopower	1.91	2.06
Prices 2004-06	**Rs.**	**US $**
Urea (50 kg bag)	468.0	7.8
Diammonium phosphate (50 kg bag)	801.0	13.35
Triple super phosphate (50 kg bag)	801.0	13.35
Sulphate of potash	996.0	16.6
Farmyard maure	1200.0	20
Biofertilizer Biopower (1.0 kg packet)	100.0	1.6

CS: Cropping System. Biofertilizer Biopower (seed inoculation at sowing). NPK @ (120-90-60) kg/ha. Farmyard manure (FYM) @ 20 t/ha. FYM * (N equivalent + P make up dose). (US $1.0 = Rupees 60 during 2004-2006)

recorded in T_9 (½ NPK + ½ FYM + Biopower) depicting the profitability of integrated use of inorganic and organic and/or biofertilizers for maize production under rainfed condition.

Conclusion: The investigation presented in this study indicated some distinct benefits of IPNM over use of mineral fertilizers. The results of this study showed that IPNM of ½ NPK + ½ FYM + Biopower in T_9 was most appropriate and economical for better yield of maize in rainfed areas. The results confirmed that besides increasing the crop yield, IPNM saved mineral fertilization which effected sustainable agricultural production in less fertile soils of rainfed Pothwar region of Pakistan. The higher nutrient concentration in maize demonstrated more efficient use of applied nutrients by IPNM. More intensive and systematic studies are required to provide a better understanding of the usefulness of IPNM in making crop production more profitable income generating activity for small farmers of rainfed Pothwar region of Pakistan. Integrated plant nutrient management is going to be the mainstay in the next millennium.

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