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Maize yield and soil properties as influenced by integrated use of organic, inorganic and bio-fertilizers in a low fertility soil

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Abstract

A field experiment was conducted to investigate the effect of integrated use of organic and inorganic fertilizers in a low fertility soil at Agricultural Research Institute, Tarnab, Peshawar. The experiment comprised of ten treatments arranged in a RCB design with three replications. The treatments were control, 50% of recommended NPK, 100% of recommended NPK and then each NPK treatment combined either with farm yard manure (FYM), humic acid or Azotobacter inoculum alone and in combinations. The results showed that combining organic sources with 50% of recommended NPK fertilizers produced the highest grain and biological yields of maize over the 50% NPK treatment and were statistically at par with those receiving 100% NPK fertilizers. Almost the same trend was observed for leaf area index and grain harvest index. Moreover, the net return was also greatest when organic sources were combined with 50% of recommended NPK fertilizers. Among organic sources, the effect of FYM was more prominent. The effect of FYM was further enhanced when Azotobacter incoculum was also added. However, the effect of humic acid was not evident neither with 100% nor with 50% of recommended NPK fertilizers. The soil analysis after crop harvest revealed that soil organic matter, total N, extractable P and K, EC and total soluble salts were all greatest for treatment receiving organic sources with 50% of recommended NPK fertilizers. Soil pH on the other hand was lowest in the corresponding treatments. These results thus suggest that integrating organic sources with 50% of recommended NPK fertilizers are appropriate for sustainable crop production on a low fertility soil.

Keywords: *Azotobacter inoculum, farmyard manure, humic acid, mineral fertilizers, soil fertility*

Introduction

The cultivable land is a limited resource and its linear expansion is not possible, the concern regarding increased crop production on sustainable basis has, therefore, led to the development of new strategies in order to maintain and protect the current soil resources and to feed the present and future generations (Harris and Bezdicek, 1994). The issue is directly related to maintain the soil quality, which refers to the soil's capacity to support crop growth without resulting in soil degradation or otherwise harming the environment (Gregorich and Acton, 1995; Miller and Wali, 1995). Normal crop growth requires sixteen nutrient elements to be present in soil solution in adequate and balance amounts (Rashid, 1996). Out of these sixteen nutrients, if a nutrient is limited, in quantity in relation to plant requirements, must be supplemented through external application to the soil or directly to the crop.

After the green revolution in Pakistan and introduction of mineral fertilizers, agriculture scientists worked extensively on such limiting nutrients and prescribed a specific dose of fertilizers for optimum production of various crops called general fertilizer recommendations e.g. for maize crop 120:90:60 kg ha^{-1} N:P_2O_5:K_2O has been recommended. But with extensive cropping intensity (100-115%), high yielding varieties, low fertilizer input and high rate of decomposition of soil organic matter due to arid and semi-arid climate, soil got further exhausted with respect to plant nutrients. Previous investigations showed that good crop production can be achieved in such soil only after ensuring balanced quantity of nutrients through balanced fertilization (Sharif *et al.,* 2004) while other scientist like Tollesa *et al.* (2001) reported that the inclusion of organic sources of nutrients in the fertilization program, besides nutrient supply, improves the nutrient use efficiency of the added synthetic fertilizers by reducing their loss and enhancing their availability to the associated crop. Kumar and Puri (2001) and Chan *et al.* (2007) also verified the results of Tollesa *et al.* (2001) by reporting increased crop production through application of organic manures at different rates along with different rates of inorganic fertilizers. This showed that the role of organic sources of nutrient application is well established in enhancing soil

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fertility and crop productivity, yet it was suspected whether inorganic fertilizer recommendations still work for optimum crop production in a low fertility and exhausted soils and whether low soil fertility, exhausted through continuous cropping, can be reclaimed through recommended dose of NPK fertilizers alone? Furthermore, if some other sources of plant nutrients like organic fertilizers are to be added, then how much is their impact when added along with recommended dose and 50% of the recommended dose of NPK fertilizers? There is however evidence that combining organic and inorganic sources of nutrients produced better crop yields on sustainable basis (e.g. Idris *et al.,* 2001; Shah and Ahmad, 2006). This present research work was therefore conducted to assess the potential of the recommended dose of inorganic fertilizers and its 50% amount alone and in combination with different doses of farmyard manures, *Azotoabcter* inoculum and humic acid for the restoration of soil productivity in a very low fertility soil that has been continuously cropped with cereals and had been treated only with chemical fertilizers of different doses during experimentation for the last 30 years.

Materials and Methods

A field experiment was conducted at Research Farm of Agricultural Research Institute, Tarnab, Peshawar, Khyber Pakhtunkhwa, Paksitan. The experimental site was located at 34^o N, 71.3^o E and at an altitude of 400 m above sea level. Composite soil samples from 0-20 cm depth in three replicates were collected for pre-sowing analysis of the experimental site (Table 1).

Table 1: Physico-Chemical Properties of the Experimental Site Before Sowing

Property	Unit	Mean Value
Clay	%	32.3
Silt	%	48.0
Sand	%	19.7
Textural Class	…….	Silty Clay Loam
pH (1:5)	……	8.0
EC. (1:5)	dS m^{-1}	0.1
Organic matter	%	0.61
Lime ($CaCO_3$)	%	14.8
Total N	%	0.03
Total mineral N.	mg kg^{-1}	28.6
AB-DTPA extractable P	mg kg^{-1}	3.56
AB-DTPA extractable K	mg kg^{-1}	115

The experiment comprised of ten treatments arranged in a randomized complete block (RCB) design with three replications (Table 2). The treatments were **1)** control, **2)** recommended NPK (120:90:60 N:P_2O_5:K_2O kg ha^{-1}), **3)** recommended NPK with FYM at 10 Mg ha^{-1}, **4)** recommended NPK with humic acid at 3 kg ha^{-1}, **5)** recommended NPK with *Azotobacter* inoculum at 1.5 kg ha^{-1}, **6)** 50% of recommended NPK, **7)** 50% of recommended NPK with FYM at 20 Mg ha^{-1}, **8)** 50% of recommended NPK with FYM at 20 Mg ha^{-1} and humic acid 6 kg ha^{-1}, **9)** 50% of recommended NPK with FYM at 20 Mg ha^{-1} and *Azotobacter* inoculum 1.5 kg ha^{-1}, and **10)** 50% of recommended NPK with FYM at 20 Mg ha^{-1}, humic acid 6 kg ha^{-1} and *Azotobacter* inoculum. Maize (*Zea maize* L.) variety (*Azam*) was sown in July, and harvested in October, 2008.

Well rotten FYM was applied one month before sowing and mixed in the soil. In case of recommended NPK, the fertilizer N was applied in two splits. All the P_2O_5 and K_2O fertilizers were applied at the time of sowing. In case of 50% of recommended NPK, all the N, P_2O_5 and K_2O fertilizers were applied at the time of sowing. Humic acid (HA) was applied to the soil in solution form after sowing. Azotobacter inoculum (AI) was applied as seed treatment. Maize (*Azam*) was planted in a plot of 3 x 5 m size with four rows and with row to row distance of 75 cm apart.

The field was irrigated as and when needed. Weeds were controlled manually. The crop was harvested on maturity. Data was recorded on grain yield, biomass yield, number of cobs $plant^{-1}$, leaf area index, and harvest index and on soil organic matter, total N, available P and K, soil pH, EC and total soluble salts after the post harvest soil analysis of each fertilizer treatment using standard procedures briefly described below;

At physiological maturity biological yield was recorded after complete sun drying of the harvested crop from each plot and expressed in kg per ha. Grain yield was recorded after cobs from each plot were separated, air dried, shelled, cleaned and weighed. Grain yield per ha was worked out and expressed in kg ha^{-1}. Number of cobs per plant were determined by dividing the total number of cobs in the plot by the total number of plants in the same plot. Leaf area index (LAI) was calculated as per the procedure given by Sestak *et al*. (1971).

LAI = Total leaf area per plot/ Total land area per plot

Harvest index (HI) is defined as the ratio of economic yield to total biological yield (Donald, 1962) and expressed in percentage as indicated below:

$$HI\ (\%) = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Total biological yield (kg ha}^{-1})} \times 100$$

Soil texture was determined by the hydrometer method as described by Tagar and Bhatti (1996). Organic matter in soil samples was determined by the Walkely-Black procedure as described in Nelson and Sommers (1996). Soil pH was measured in a 1:5 (Soil:H_2O) suspension after 30 minutes of stirring and read on pH meter (Model German Type B-124 using glass and calomel electrodes) (McClean, 1982). Electrical conductivity was determined by the procedure described by Rhoads (1996). AB-DTPA extractable P and K were determined by the procedure described by Soltanpour and Schwab (1977) using spectrophotometer and flame photometer, respectively. Total N in soil was determined by the Kjeldhal method of Bremner (1996).

The data was statistically analyzed using analysis of variance technique and the means were compared using LSD test at the 0.05 level of significance when the F-values were found significant (Steel and Torrie, 1984).

Table 2: Treatment combinations of various mineral, organic and bio-fertilizers

Treatment	$N:P_2O_5:K_2O$ (kg ha^{-1})	FYM (Mg ha^{-1})	Humic acid (HA) (kg ha^{-1})	*Azotobacter* Inoculum (AI) (kg ha^{-1})
Control (T1)	0	0	0	0
RNPK (T2)	120:90:60	0	0	0
RNPK+FYM10 (T3)	120:90:60	10	0	0
RNPK+HA3 (T4)	120:90:60	0	3	0
RNPK+AI1.5 (T5)	120:90:60	0	0	1.5
RNPK50 (T6)	60:45:30	0	0	0
RNPK50+FYM20 (T7)	60:45:30	20	0	0
RNPK50+FYM20+HA6 (T8)	60:45:30	20	6	0
RNPK50+FYM20+AI1.5 (T9)	60:45:30	20	0	1.5
RNPK50+FYM20+A6+AI1.5 (T10)	60:45:30	20	6	1.5

RNPK: Recommended NPK dose, RNPK50: 50% of the recommended NPK, FYM: farmyard manure; HA: humic acid; AI: *Azotobacter* inoculum

Results and Discussion

Grain Yield

The results showed that fertilizer treatments significantly ($P<0.05$) increased the grain yield of maize over control (Table 3). The maximum grain yield of 3202 kg ha^{-1} was obtained in treatment receiving 50% of recommended NPK along with FYM at 20 Mg, humic acid at 6 kg and *Azotobacter* inoculums 1.5 kg ha^{-1}. The next highest grain yield of 3167 kg ha^{-1} was obtained in treatment receiving 50% of recommended NPK along with FYM at 20 Mg and *Azotobacter* inoculum 1.5 kg ha^{-1} and this was statistically at par with above treatment. This means that addition of humic acid at 6 kg ha^{-1} with 50% of recommended NPK fertilizers + FYM at 20 Mg + *Azotobacter* inoculums 1.5 kg ha^{-1} had no significant role in increasing the grain yield of maize. These results further showed that addition of organic fertilizers and/or *Azotobacter* inoculum with recommended NPK fertilizers did not significantly increase the grain yield of maize compared with recommended NPK alone treatment.

The grain yield of maize obtained with 50% of recommended NPK treatment was 2200 kg ha^{-1} compared with 2811 kg ha^{-1} with 100% of recommended NPK treatment. It is interesting to note that combining organic fertilizer with recommended NPK treatment did not significantly increase the grain yield of maize over recommended NPK treatment. However, combining FYM at 20 Mg ha^{-1} with 50% of recommended NPK treatment produced grain yield of 2856 kg ha^{-1} which is statistically at par with 2811 kg ha^{-1} obtained with 100% of recommended NPK treatment. These results suggested that combining organic fertilizers with 100% recommended dose of NPK fertilizers was ineffective in increasing the grain yield of maize compared with treatment receiving 100% of recommended NPK fertilizers. However, combing organic fertilizers with 50% of recommended dose of NPK fertilizer significantly increased the grain yield of maize compared with treatment receiving 50% of recommended NPK fertilizers. It was evident from the results that the grain yield produced with treatment receiving 50% of recommended NPK fertilizers plus organic fertilizers was almost equal to that produced with 100% of NPK treatment. Furthermore, the effect of all organic sources was same when applied with 100% of recommended NPK fertilizers but varied when applied with 50% of recommended NPK fertilizers. Among organic sources, the effect of FYM was more prominent. The effect of FYM was further enhanced when *Azotobacter* incoculum was also added. However, the effect of humic acid was not evident neither with 100% nor with 50% of recommended NPK fertilizers.

The economic analysis (Table 4 and Figure 1) revealed that the maximum net return of Rs. 12506 ha^{-1} was obtained with treatment receiving 50% of recommended NPK plus FYM at 20 Mg and *Azotobacter* inoculum at 1.5 kg ha^{-1} followed closely by Rs. 12496 ha^{-1} with treatment receiving 50% of recommended NPK plus FYM at 20 Mg, humic acid at 6 kg and *Azotobacter* inoculum at 1.5 kg ha^{-1}. The next highest net return was obtained with treatment receiving 50% of recommended NPK either with FYM at 20 kg ha^{-1} (Rs. 7952 ha^{-1}) or FYM at 20 Mg and humic acid at 6 kg ha^{-1} (Rs. 8204 ha^{-1}). The net return with the use of 100% recommended NPK alone was Rs. 7173 ha^{-1} but was reduced significantly to Rs. 3681 ha^{-1} when used with organic sources (humic acid at 3 kg ha^{-1}). Our findings are consistent with the findings of a number of workers (Mishra *et al.*, 1995; Al-Abdulsalam, 1997; Pandey *et al.*, 1998; Radwan, 1998) who demonstrated that under certain environmental and soil conditions, application of FYM and inoculation with *Azotobacter* improved crop yield. Microbial inoculum not only increase the nutritional assimilation of plant (total N, P and K), but also improve soil properties, such as organic matter content and total N in soil (Wu *et al.,* 2005).

Biological Yield

The results revealed that fertilizer treatments had significant ($p<0.05$) effect on biological yield of maize compared with the control treatment (Table 3). It was noted that biological yield with recommended NPK dose was 14 Mg ha^{-1} which increased significantly to 15.7 Mg ha^{-1} when recommended dose of NPK was supplemented with FYM at 10 Mg ha^{-1}. However, supplementing recommended dose of NPK fertilizers with humic acid or *Azotobacter* inoculum did not significantly improve the biological yield of maize

Table 3: Effect of organic and inorganic fertilizers on yield and yield components of maize crop

Treatment	Grain Yield (kg ha^{-1})	Biological Yield (Mg ha^{-1})	No. Cobs ($plant^{-1}$)	Leaf Area Index	Harvest Index (%)
Control	1656	10.1	0.96	1.19	16.44
RNPK	2811	14.0	1.02	2.57	20.04
RNPK+FYM10	2889	15.7	0.99	3.23	18.46
RNPK+HA3	2633	13.3	0.97	2.37	19.85
RNPK+AI1.5	2653	13.4	1.03	2.48	19.86
RNPK50	2200	12.3	0.99	1.87	17.93
RNPK50+FYM20	2856	15.7	1.03	2.85	18.24
RNPK50+FYM20+HA6	2924	15.6	1.03	2.29	18.77
RNPK50+FYM20+AI1.5	3167	16.1	1.03	3.26	19.73
RNPK50+FYM20+HA6+AI1.5	3202	16.2	1.01	3.20	19.80
LSD (P<0.05)	312	1.2	ns	0.76	1.65
C.V %	6.75	4.93	3.78	17.52	5.09

Table 4: Economic analysis of different sources of plant nutrients ha^{-1}

Treatment	Value of Total yield (Rs)	Value of increased yield (Rs.)	Total cost of input (Rs.)	Net return (Rs.)
Control	33284	0	0	0
RNPK	53354	20070	12897	7173
RNPK+FYM10	56146	22862	16897	5965
RNPK+HA3	50162	16878	13197	3681
RNPK+AI1.5	50542	17258	13097	4161
RNPK50	43100	9816	6448	3368
RNPK50+FYM20	55684	22400	14448	7952
RNPK50+FYM20+HA6	56536	23252	15048	8204
RNPK50+FYM20+AI1.5	60438	27154	14648	12506
RNPK50+FYM20+A6+AI1.5	61028	27744	15248	12496

Prices of input in Rupees have been taken from the list of fertilizer rates during 2007-2008 given at http://www.nfdc.gov.pk/web-page%20updating/prices.htm; The rates are; DAP: 2934/bag, Urea: 471/bag, SOP: 1497/bag, FYM: 400/ton, Humic acid: 100/kg and *Azotobacter* Innoculum: 133/kg

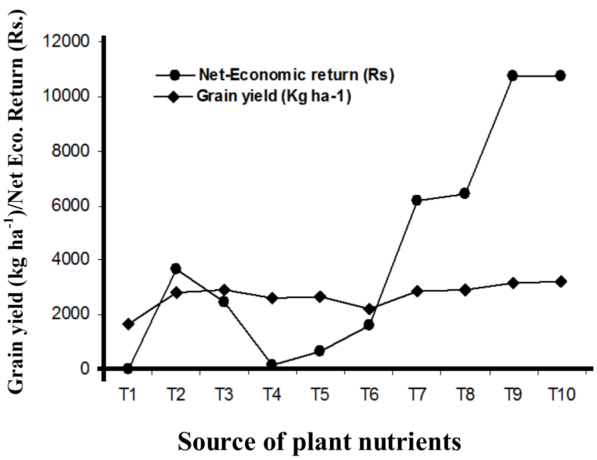

Figure 1: Effect of different sources of plant nutrients on grain yield and net-economic return on low fertility soil

These results suggested that integrated use of organic and inorganic fertilizers were more efficient in increasing the biological yield of maize compared with NPK alone fertilizers. Furthermore, the influence of combining organic sources with NPK fertilizers was much stronger when combined with low (50% of recommended dose) than with high (100% of recommended) dose. These results are consistent with the results of Matsi *et al.* (2003) and Badruddin *et al.* (1994) who reported enhanced biological yield with manure treated plots and attributed this increase in biological yield to the enhanced soil fertility and improved soil physical conditions due to FYM application. Enhanced biological yield in treatments treated with organic fertilizers (FYM, humic acid and *Azotobacter*) along with half of the recommended NPK mineral fertilizer might be attributed to the vigorous root and shoot growth due to increased soil organic matter that subsequently improved soil physical conditions, water holding capacity and enhanced soil fertility leading to good crop stand till maturity (Eqtidar *et al.,* 2006; Swarap and Wanjari, 2000).

Table 5: Means of post-harvest soil fertility parameters at 0-20 cm depth

Treatment	OM	Total N	Ext. P	Ext. K	pH	EC	TSS
	(g kg^{-1})		(mg kg^{-1})			(d Sm^{-1})	(g kg^{-1})
T1	2.60	0.13	7.70	120	8.17	0.10	0.34
T2	3.23	0.16	18.09	167	8.07	0.12	0.40
T3	4.27	0.21	19.53	162	8.13	0.12	0.39
T4	3.53	0.18	18.04	173	8.10	0.11	0.37
T5	3.10	0.16	18.49	178	8.13	0.12	0.38
T6	2.90	0.15	11.08	137	8.17	0.11	0.35
T7	7.53	0.38	18.30	183	7.97	0.13	0.43
T8	7.43	0.39	17.62	190	7.97	0.14	0.45
T9	7.46	0.35	17.45	190	8.04	0.15	0.48
T10	7.50	0.48	18.06	193	7.94	0.15	0.50
LSD ($P<0.05$)	0.12	0.007	4.636	22	0.14	0.02	0.007
C.V %	15.04	15.04	16.44	7.61	1.02	9.02	9.02

T1: Control; T2: RNPK, T3: RNPK+FYM10, T4: RNPK+HA3, T5: RNPK+AI1.5, T6: RNPK50, T7: RNPK50+FYM20, T8: RNPK50+FYM20+HA6, T9: RNPK50+FYM20+AI1.5, T10: RNPK50+FYM20+HA6+AI1.5, OM: Organic matter; Ext. P: Extractable P; Ext.K: Extractable K

compared with alone recommended NPK treatment. However, supplementing 50% of recommended NPK fertilizers with any of the organic sources alone or in combinations significantly increased the biological yield of maize compared with alone 50% recommended NPK treatment. Although the biological yield was highest in treatment receiving 50% of recommended NPK along with FYM at 20 Mg, humic acid at 6 kg and *Azotobacter* at 1.5 kg ha^{-1}, it was statistically at par with all those treatments receiving 50% of recommended NPK with any of the organic sources (FYM, humic acid or *Azotobacter* inoculum).

Number of Cobs Plant^{-1}

Fertilizer treatments did not significantly ($p<0.05$) increase the number of cobs plant^{-1}. This might be due to the genetic character of the variety which could not be easily changed without genetic engineering or breeding. The *Azam* variety has been genetically evolved as one cob plant^{-1} bearing variety. But, generally, those plots that received recommended NPK dose with or without organic and bio-fertilizer or those plots that received organic or bio-fertilizers in combination with half of the recommended NPK dose showed better results (Table 3).

Leaf area index and harvest index

The results showed that leaf area index and harvest index increased with increasing levels of fertilizers. The leaf area index in the control was 1.19 which increased to 1.87 with 50% of the recommended NPK dose and to 2.57 with recommended NPK dose. The leaf area index further increased when mineral fertilizers were applied in combination with organic sources. Thus, with recommended NPK and 10 Mg ha^{-1} FYM treatment (RNPK + FYM10), the leaf area index was 3.23 and with 50% of the recommended NPK plus 20 Mg FYM and 1.5 kg ha^{-1} *Azotobacter* inoculum (RNPK50 + FYM20 + AI1.5), leaf area index was 3.26 which was the highest amongst all treatments. This may be attributed to the role of N in vegetative growth of the plants and its influence on utilization of P, K and other nutrient elements (Inamulhaq and Jakhro, 1996). Furthermore, FYM ensure slow release of N through its mineralization and N-fixation through *Azotobacter* ensured N supply to plants throughout their life cycle causing more vegetative growth (Ali and Bhatti, 2008).

Our data further showed that *Azotobacter* inoculum (AI1.5) application significantly ($p<0.05$) improved the harvest index over the treatments receiving no inoculum. This might be due to the better utilization of readily available fertilizer nitrogen or nitrogen from biological nitrogen fixation (BNF) which made plant more efficient in photosynthetic activity. Grain becomes a dominant sink of plant nutrients at their maturity stage and all the photo-assimilates are deposited in the grains as compared to other parts of the plant (Ali and Jan, 2005).

Soil Parameters

Soil organic matter and total N content

Different fertilizer sources significantly ($p<0.05$) affected the organic matter and total N content of soil (Table 5). The treatment with recommended NPK along with 10 Mg ha^{-1} FYM (RNPK + FYM10) showed 32% increase in soil organic matter over the recommended NPK (RNPK) alone while with 50% NPK and 20 Mg ha^{-1} FYM (RNPK50+FYM20) in the presence or absence of humic acid and *Azotobacter* inoculum, soil organic matter content increased approximately two fold over the recommended NPK (RNPK) alone. The pattern of total N content was the same as with soil organic matter. This much increase in soil organic matter could be expected even in the first remedial measure when the initial content of soil organic matter is very low (2.6 g kg^{-1} in the present experiment) as compared to the sufficient level of soil organic matter (15 to 20 g kg^{-1} in normal soils). Our findings are supported by the classical experiment at Hoosfield (Rothamsted), where annual application of manure at a rate of 35 Mg ha^{-1} to continuous spring barley for over 140 years resulted in an exponential increase in soil organic C levels of about three-fold over that in the unfertilized soil (Johnston, 1986). Under tropical conditions in the northwest of India, yearly applications of 45 tonne ha^{-1} manure increased the soil organic C level by approximately 4 fold i.e. from an initial value of 4.7 g kg^{-1} soil in 1967 to 18 g kg^{-1} soil in 1995 (Gupta *et al*., 1996). Our results in Table 5 further showed that sole NPK dose increased soil organic matter and total N content over the control significantly but there was still a lot of potential of increasing soil organic matter and total N content and hence the soil fertility of the poor soils through the application of organic sources of plant nutrients without compromising the net economic return of the field.

Available P

The AB-DTPA extractable P content of soil after crop harvest was also significantly ($P<0.05$) increased by the fertilizer treatments compared with the control (Table V). The results showed that NPK recommended dose (RNPK) in the presence or absence of organic sources of plant nutrients (T2 to T5) recorded soil available P in adequate level (>15 mg kg^{-1}) while half of the recommended P dose (RNPK50), recorded the available P content in the marginal range (10-15 mg kg^{-1}). Supplementing this RNPK50 with 20 t ha^{-1} FYM (T7 to T10) increased soil available P level again to the range of adequacy whilst the humic acid or *Azotobacter* inoculum effect on soil available P was non-significant. The surface application of P both in mineral form and P got released from FYM through mineralization might have increased available P content in these treatments. These results are in agreement with those of Morari *et al*. (2008) who reported higher available P with the use of organic fertilizers. Garg and Bahl (2008) also reported that amongst different organic manure sources, FYM supply the highest amount of Olsen extractable P. The increased microbial activity with the combined application of farmyard manure and P fertilizers increased the cycling of P through microbiological processes, thus decreasing P fixation and increased plant availability with time (Ayaga *et al*., 2006).

Available K

Available K content in the pre-sowing soil properties (Table 1) was below the adequate level (< 120 mg kg^{-1}). The recommended NPK dose (RNPK) with or without organic sources of plant nutrients (T2-T5) increased the available K content from 166 to 177 mg kg^{-1} (Table 5). In case of half of the recommended NPK (RNPK50) application, the available K content was 136 mg kg^{-1}. Application of 20 Mg ha^{-1} FYM along with RNPK50 with or without humic acid and *Azotobacter* inoculum (T7 to T10), increased the available K content to the range of 183 to 193 mg kg^{-1}. It was however observed that humic acid and *Azotobacter* inoculum did not significantly affect the K content in soil. These results suggested the superiority of half of the recommended NPK dose (RNPK50) along with application of organic sources (FYM) over the sole recommended NPK dose (RNPK) as it increased the K level towards K sustainability on such poor soils on one hand whilst on the other hand recorded increased net economic return. Our results are supported by the findings of Kaihura *et al*. (1999) who revealed that FYM application increased soil K by two fold to that of farmer practice. Blaise *et al*. (2005) found that K balance was positive only when FYM was applied.

Soil pH

The results showed that soil pH was not influenced significantly by any of the fertilizer treatments receiving either 100% of recommended NPK alone or in combination with FYM, humic acid or *Azotobacter* inoculum (Table 5). However, the combination of 20 Mg ha^{-1} FYM with 50% of recommended NPK fertilizers significantly ($P<0.05$) reduced the soil pH (Table 5). The maximum reduction (3.3%) was noted in the treatment that received FYM, humic acid and *Azotobacter* inoculums along with the half NPK fertilizer dose. Thus, this experiment established the results that on alkaline silt loam soils, soil pH can be reduced or at least any further increase in soil pH can be saved, if tried to supply maximum nutrient requirements from the organic sources. Our results are in line with the results of the Simek *et al.* (1999) who reported that in the absence of lime, the effects of the manure plus inorganic fertilizers were to reduce soil pH. Although, in our case, the soil was moderately calcareous, the reduction in soil pH might be the result of two simultaneous processes, i.e, the production of organic acids during organic fertilizers decomposition (Bolan, 1994) and the downward movement of lime with peculating water to sub-surface soil (Hao and Chang, 2003).

Soil electrical conductivity (EC) and total soluble salts (TSS)

The results showed that EC and TSS content increased with increasing fertilizer level (Table 5). From our data a significant increase in EC was observed in the treatments receiving 50% NPK (RNPK50) along with 20 Mg ha^{-1} FYM either in the presence or absence of humic acid and inoculum *Azotobacter* (T7-T10). Similar results were also observed for TSS and these results confirmed the findings of Hao and Chang (2003) who reported that livestock manure contains considerable salt and its application to agricultural land may result in an accumulation of salt in soil. Although mineral fertilizers are soluble salts in itself, the increase in EC was non-significant under recommended NPK dose (RNPK) and its combination with 10 tons ha^{-1} FYM, 1.5 kg *Azotobacter* and 3 kg HA (T3, T4 and T5, respectively) and this might be due to greater downward movement of soluble ions under irrigation on such silt loam soils. The non-significant increase in EC in T2-T5 over the control (T1) might be considered as one of the indications of the insufficiency of recommended dose of NPK fertilizers for such poor soils.

Conclusion

The experiment has shown that combining organic sources with 50% of recommended NPK fertilizers produced significantly highest grain and biological yields of maize over the 50% NPK treatment. Moreover, the net return was also greatest when organic sources were combined with 50% of recommended NPK fertilizers. Among organic sources, the effect of FYM was more prominent especially when combined with *Azotobacter* incoculum. However, the effect of humic acid was not evident neither with 100% nor with 50% of recommended NPK fertilizers. The soil analysis after crop harvest revealed that soil organic matter, total N, extractable P and K, EC and total soluble salts were all greatest for treatment receiving organic sources with 50% of recommended NPK fertilizers. These results thus suggest that integrating organic sources with 50% of recommended NPK fertilizers are appropriate for sustainable crop production on a low fertility soil.

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