Research Article

Effect of Long-Term Fertilization on Yield Attributing Character and Economics of Maize in Maize-Wheat Cropping System

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Abstract

A long-term fertilization experiment on maize-wheat cropping system was initiated since 1983 at Birsa Agricultural University farm, Ranchi, to study the effect of continuous application of different fertilizer levels on productivity economics nutrient utilization and soil fertility. The present investigation was part of this long term experiment started after 29th crop cycle during 2013-14 and 2014-15 to find out the effect of long term fertilization on productivity and economics of maize in maize-wheat cropping system. Results showed that balance fertilization of maize-wheat cropping system with $N_{120}P_{80}K_{40}$ kg/ha produced maximum grain yield (42.09 q/ha) of maize with gross return `56,897/ha, net return of `26,785/ha and B:C ratio (0.89). Continuous application of 120 kg N/ha alone for more than 30 years drastically reduced the grain yield of maize (9.38 q/ha) which was 29.05% less than control (13.22 q/ha, grain yield of maize). However application of 40 kg P_2O_5/ha along with nitrogen remarkably improve the productivity of individual crop as well as cropping system.

Keywords: Long-term fertilization, Maize, yield attributes, yield and economics

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Introduction

Maize (*Zea mays L.*) having high yield potential and multi-faceted use referred as the queen of cereals which is fertilizer responsive and exhibit full potential when supplied with adequate quantities of nutrients at proper time. Among the various production factors, fertilizer management is a key factor for increasing the yield of crop. The nitrogen requirement of crop is more than any other nutrients and its deficiency at any stage of growth, especially tasseling and silking stage may leads to virtual crop failure. While, continuous application of only nitrogen drastically reduces the grain yield over years. This is due to gradual increase in exchangeable acidity, deficiency of basic cations and imbalance among the nutrients [1].

Soils of Jharkhand are acidic (Alfisol) in reaction, low in availability of nitrogen and phosphorus, medium to high in potassium and poor in water retention capacities. Alfisols are abundant in Fe, Al and Mn which creates nutrient imbalance in the soil resulting in the deficiency of certain plant nutrients. The average yield of cereals particularly maize in these acidic soils reveal low productivity, so there is need of sustainable production through the resource management and to maintain the soil fertility through judicious application of fertilizer. Another problem compounded the common use of imbalance fertilizers, often only one nutrient namely nitrogen, resulting in widening of N, P, K ratio [2]. The imbalance use of fertilizer is a threat to crop productivity, soil fertility and sustainability of agriculture [3].

Materials and Methods

A long term field experiment was started since 1983 at Birsa Agricultural University Farm, Ranchi which is situated at 23°.34' N latitude and 85°.31' E longitudes at an altitude of 645.45 meter above the mean sea level. It falls under humid sub tropical climatic conditions, which is characterized by the features of hot dry summers and cool dry winters. The present investigation was part of this long term experiment started after 29th crop cycle during 2013-14 and continued for two consecutive years. At the beginning (1983), experimental soil was sandy-loam in texture having *p*H 6.4, available N 260 kg/ha, available P 19.5 kg/ha and available K 195 kg/ha. However, before start of present investigation it varies depending on the fertilizer level. Maximum reduction in *p*H 4.65 was observed in plot receiving only nitrogen ($N_{120}P_0K_0$ kg/ha). The experiment was laid out in partially confounded design with 18 treatments and one control replicated four times. Treatments comprising of three levels of nitrogen: 40, 80 and 120 kg

N/ha, three levels of phosphorus: 0, 40 and 80 kg P_2O_5/ha and two levels of potassium: 0 and 40 kg K_2O/ha. Variety used for maize and wheat was 'Suwan' and 'K-9107' respectively. During *Kharif*, first year maize was sown in the third week of June and harvested in the second week of October, whereas, during second year maize sown in the third week of June and harvested in the fourth week of September. Similarly, during *Rabi*, first year wheat was sown in the first week of December and harvested in the second week of April, whereas during second year wheat was sown in the first week of November and harvested in the second week of April. Nitrogen, phosphorus and potassium were applied through urea, di-ammonium phosphate and muriate of potash, respectively. In maize, 1/3 dose of nitrogen and full doses of phosphorus and potassium were applied at the time of sowing, while remaining nitrogen was equally side dressed at knee hight and tesseling stages. At physiological stage of maturity, cobs were harvested manually. After drying in the sun, the grains were separated out and weighed to record economic yield. After harvesting of *Kharif* crop, wheat was sown in the same plots with same fertilizer dose. Data obtained from the experiment were properly analyzed using the F- test, the procedures given by [4].

Results and Discussion

Yield attributes and yield

Plant population, number of cob per plant, number of grains per cob, 100-grain weight were significantly influenced by long term fertilization in maize-wheat cropping system. Consequently, the balanced fertilizer dose exhibited better growth and having superior yield attributes which leads to higher yield (**Tables 1-5**).

Table 1 Plant population/ha at maturity of maize influenced by long term fertilizer application in maize-wheat cropping system (Pooled)

Treatment	K_0			K_{40}		
	P_0	P_{40}	P_{80}	P_0	P_{40}	P_{80}
N_{40}	50772	51337	52726	51440	52006	53369
N_{80}	49254	52160	53524	51132	53061	53678
N_{120}	47016	53601	53678	50489	53447	54372
Control	52812					
SEm±	906					
CD (P=0.05)	NS					
CV %	4.70					

Table 2 Number of cob per plant of maize influenced by long term fertilizer application in maize-wheat cropping system (Pooled)

Treatment	K_0			K_{40}		
	P_0	P_{40}	P_{80}	P_0	P_{40}	P_{80}
N_{40}	1.00	1.28	1.15	1.00	1.10	1.40
N_{80}	1.00	1.35	1.18	1.00	1.10	1.43
N_{120}	1.00	1.18	1.50	1.00	1.40	1.65
Control	1.00					
SEm ±	0.03					
CD (P=0.05)	0.09					
CV %	7.05					

Table 3 Number of grains per cob of maize influenced by long term fertilizer application in maize-wheat cropping system (Pooled)

Treatment	K_0			K_{40}		
	P_0	P_{40}	P_{80}	P_0	P_{40}	P_{80}
N_{40}	306	328	340	317	357	381
N_{80}	268	343	364	301	389	399
N_{120}	236	366	374	267	410	438
Control	264					
SEm±	12.48					
CD (P=0.05)	NS					
CV %	10.8					

Table 4 100-grain weight (g) of maize influenced by long term fertilizer application in maize-wheat cropping system (Pooled)

Treatment	K_0			K_{40}		
	P_0	P_{40}	P_{80}	P_0	P_{40}	P_{80}
N_{40}	19.39	20.16	21.10	18.06	21.71	22.84
N_{80}	18.24	21.04	22.38	17.54	22.29	22.88
N_{120}	17.83	21.55	23.59	17.45	23.47	25.25
Control	17.47					
SEm ±	0.33					
CD (P=0.05)	NS					
CV %	4.41					

Table 5 Grain yield (q/ha) of maize influenced by long term fertilizer application in maize-wheat cropping system (Pooled)

Treatment	K_0			K_{40}		
	P_0	P_{40}	P_{80}	P_0	P_{40}	P_{80}
N_{40}	13.98	25.66	27.51	11.99	29.11	31.96
N_{80}	11.15	27.65	32.47	9.86	31.13	32.91
N_{120}	9.38	27.91	39.23	8.28	39.54	42.09
Control	13.22					
SEm±	1.19					
CD (P=0.05)	3.31					
CV %	14.38					

Balance and higher fertilizer application recorded more yield attributing character of maize as compared to rest of the treatments (**Figures 1a** and **1b**). Maximum plant population/ha (54,372), number of cob/plant (1.65), grains/cob (438) and test weight (25.25) were recorded with application of $N_{120}P_{80}K_{40}$ kg/ha which was at par with application of $N_{120}P_{40}K_{40}$ kg/ha and $N_{120}P_{80}K_0$ kg/ha. Owning to favorable combined effect of nutrient causing vigorous growth of plants accumulating higher photosynthesis [5].

Maximum grain yield of maize (42.09 q/ha) was recorded with application of $N_{120}P_{80}K_{40}$ kg/ha which was at par with application of $N_{120}P_{40}K_{40}$ kg/ha (39.54 q/ha) and $N_{120}P_{80}K_0$ kg/ha (39.23 q/ha). Additional application of 80 kg phosphorus and 40 kg potassium along with 120 kg nitrogen per hectare increase the grain yield of maize by 348.7% in comparison to application of 120 kg/ha nitrogen alone (9.38 q/ha). This was possibly due to continuous application of nitrogen only, led to extreme lowering of soil pH whereas balance use of NPK fertilizer maintained the soil reactions and fertility status. This favorable effect might be owing to plots getting balanced fertilizer, improved the yield attributes of maize. Several workers justified the result [6].

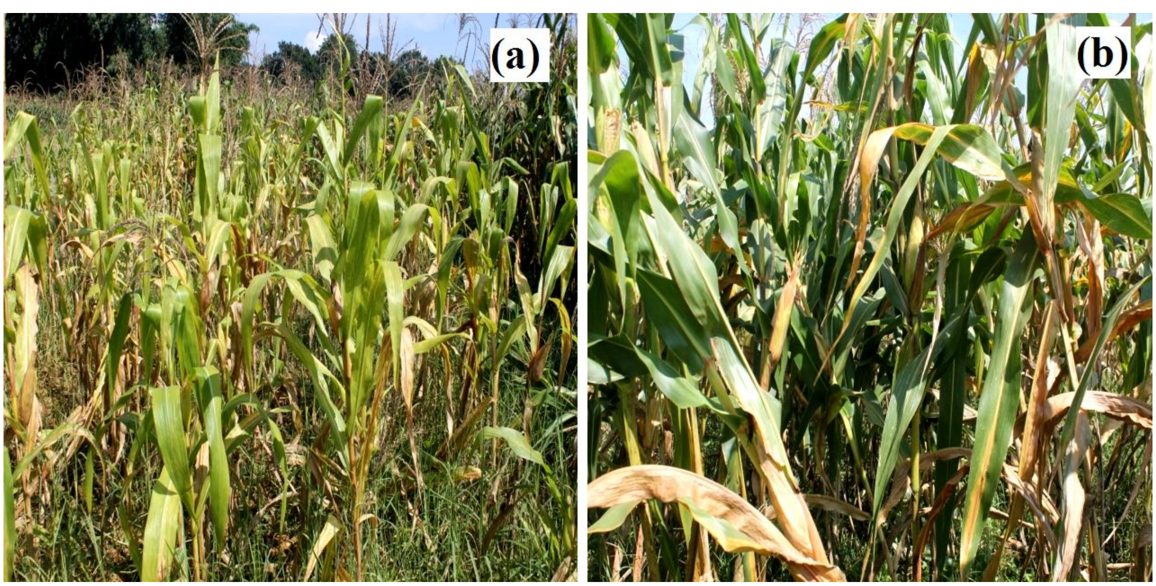

Figure 1 Maize at (a) N_{120}:P_0:k_0, (b) N_{120}:P_{30}:k_{40}

Economics

Economics of maize under long term fertilization in maize-wheat sequence showed that crop fertilized with 120 kg N /ha recorded significantly higher gross return `37,540 /ha, net return `11,497 /ha and benefit cost ratio 0.37 (**Tables 6-8**). B: C ratio in this treatment was 54.2 and 48.0% higher than maize fertilized with 80 and 40 kg N/ha while, negative B:C ratio (-0.03) was recorded under control. Though control plot gave some gross return but it gave negative net return owing to high cost of cultivation. Similar observation was found by [7].

Among phosphorus level crop fertilized with 80 kg P_2O_5 /ha recorded significantly higher net return and B:C ratio (Rs. 17,698 /ha and 0.61 respectively) which was even higher than maximum nitrogen level indicating that phosphorus was more important than nitrogen economically. Crop raised without phosphorus fertilizer gave further loss (-0.29) which was even lower than the control. Phosphorus was beneficial in term of grain yield, quality and economics of maize. This finding was also support by [8].

While, potassium level did not influenced significantly B:C ratio of maize, though higher gross return and net return Rs. 35,649 and Rs.9,580 /ha respectively was recorded in crop fertilized with 40 kg K_2O /ha, it might be due to proper growth and development of crop which ultimately gave significantly higher grain yield but did not show any marked variations.

Table 6 Gross return (Rs /ha) of maize influenced by long term fertilizer application in maize-wheat cropping system (Pooled)

Treatment	**K_0**				**K_{40}**			**Mean of N**
	P_0	**P_{40}**		**P_{80}**	**P_0**	**P_{40}**	**P_{80}**	
N_{40}	19093	34649		37164	16368	39331	43219	31637
N_{80}	15244	37413		43853	13482	42123	44657	32795
N_{120}	12824	37780		52970	11298	53470	56897	37540
Mean	15720	36614		44662	13716	44975	48258	
	P_0	P_{40}	P_{80}	K_0	K_{40}		K_0	K_{40}
N_{40}	17730	36990	40191	30302	32973	P_0	15720	13716
N_{80}	14363	39768	44255	32170	33420	P_{40}	36614	44975
N_{120}	12061	45625	54934	34525	40555	P_{80}	44662	48258
Mean	14718	40795	46460	32332	35649		32332	35649
Control	17978							
		N	P	K	N X P	N X K	P X K	N X P X K
SEm±		690	690	527	1117	912	912	1580
CD (P=0.05)		1921	1921	1467	3112	2541	2541	4401
CV %		14.11						

Table 7 Net return (Rs/ha) of maize influenced by long term fertilizer application in maize-wheat cropping system (Pooled)

Treatment	**K_0**				**K_{40}**			**Mean of N**
	P_0	**P_{40}**		**P_{80}**	**P_0**	**P_{40}**	**P_{80}**	
N_{40}	-537	9599		9753	-4639	12904	14431	6918
N_{80}	-5048	11700		15780	-8188	15033	15207	7414
N_{120}	-8131	11406		24235	-11033	25718	26785	11497
Mean	-4572	10902		16589	-7953	17885	18808	
	P_0	P_{40}	P_{80}	K_0	K_{40}		K_0	K_{40}
N_{40}	-2588	11251	12092	6272	7565	P_0	-4572	-7953
N_{80}	-6618	13367	15493	7477	7351	P_{40}	10902	17885
N_{120}	-9582	18562	25510	9170	13824	P_{80}	16589	18808
Mean	-6263	14393	17698	7640	9580		7640	9580
Control	-480							
		N	P	K	N X P	N X K	P X K	N X P X K
SEm±		690	690	527	1117	912	912	1580
CD (P=0.05)		1921	1921	1467	3112	2541	2541	4401
CV %		61.89						

Table 8 B:C ratio of maize influenced by long term fertilizer application in maize-wheat cropping system (Pooled)

Treatment	**K_0**				**K_{40}**			**Mean of N**
	P_0	**P_{40}**		**P_{80}**	**P_0**	**P_{40}**	**P_{80}**	
N_{40}	-0.03	0.38		0.36	-0.22	0.49	0.50	0.25
N_{80}	-0.25	0.46		0.56	-0.38	0.55	0.52	0.24
N_{120}	-0.39	0.43		0.84	-0.49	0.93	0.89	0.37
Mean	-0.22	0.42		0.59	-0.36	0.66	0.64	
	P_0	P_{40}	P_{80}	K_0	K_{40}		K_0	K_{40}
N_{40}	-0.12	0.44	0.43	0.24	0.26	P_0	-0.22	-0.36
N_{80}	-0.31	0.50	0.54	0.26	0.23	P_{40}	0.42	0.66
N_{120}	-0.44	0.68	0.87	0.30	0.44	P_{80}	0.59	0.64
Mean	-0.29	0.54	0.61	0.26	0.31		0.26	0.31
Control	-0.03							
		N	P	K	N X P	N X K	P X K	N X P X K
S Em ±		0.03	0.03	0.02	0.04	0.04	0.04	0.06
CD (P=0.05)		0.07	0.07	NS	0.12	NS	0.10	NS
CV %		71.66						

The interaction effect between nitrogen and phosphorus showed that, maximum gross return (Rs. 54,934 /ha), net return (Rs. 25,510 /ha) and B:C ratio (0.87) were recorded in crop fertilized with 120 kg N and 80 kg P_2O_5 /ha. Addition of 40 and 80 kg P_2O_5 /ha along with 120 kg N/ha drastically increase the gross return of maize by 278.3 and 355.5% respectively in comparison to gross return of maize with 120 kg N and 0 kg P_2O_5 /ha (Rs.12,061 /ha). As nitrogen level increased from 40 to 120 kg/ha without any phosphorus economic return gradually decreased and produced negative value of net return as well as B:C ratio of maize. This was due to low yield with high cost of cultivation. Application of P along with N might have increased the availability and uptake nutrients from the soil that had improved maize growth and produced higher yield and thereby giving high economic return.

However, interaction effect of nitrogen and potassium on economics of maize cultivation reveals that gross return and net return where significantly influenced by long term fertilization but B:C ratio of maize was not influenced by interaction effect of nitrogen and potassium, it means crop grown with or without potassium might have slightly differed but owing to cost of cultivation B:C ratio was not differed.

Maximum gross return (Rs. 48, 258 /ha) and net return (Rs.18,808 /ha) were recorded in crop fertilized with 80 kg P_2O_5 and 40 kg K_2O /ha, whereas, maximum B:C ratio (0.66) was recorded in crop fertilized with 40 kg P_2O_5 and 40 kg K_2O /ha being on par with 80 kg P_2O_5 and 40 kg K_2O /ha (0.64). Lower B: C ratio at higher phosphorus level was due to increase in cost of phosphatic fertilizer.

Highest gross return and net return (Rs. 56,897 and Rs. 26,785 /ha, respectively) were recorded in crop fertilized with balanced dose of NPK i.e. $N_{120}P_{80}K_{40}$ kg/ha which was on par with $N_{120}P_{40}K_{40}$ kg/ha and $N_{120}P_{80}K_0$ kg/ha. Although gross return and net return were significantly influenced but B: C ratio was not, because prevailing market price of grain, stone and stover was higher. It indicates that though maize grown at higher level of fertilizer dose gave a good return but it was not economically beneficial per rupee investment. Similar finding was also reported by [5] and [9].

Conclusion

Continues balance fertilization with $N_{120}P_{80}K_{40}$ kg /ha in long-term maize-wheat cropping system maintained maximum crop yield of maize (42.09 q/ha) without deteriorate the soil health even after 31^{st} crop cycle. Whereas, continues use of nitrogenous fertilizer alone drastically reduced soil fertility and yield.

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