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On-Farm Studies on Gains in Yield and Economic Return of Different NP Fertilizer Levels in Maize

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ABSTRACT

This study was conducted to determine the optimum and economic NP fertilizer level in on-farm maize trials under prevailing agro-climatic conditions at five different locations of Islamabad Capital Territory (ICT): Golra, Rawat, Thandapani, Sihala and Bharakahu. The experiment was conducted on silty-clay to loam soils with varying chemical and physical properties, and replicated thrice at each location in a randomized complete block design. The treatments on the improved open pollinated variety (OPV) Gauher included six NP levels (40:00, 40:30, 40:60, 80:00, 80:30 & 80:60). The soil analyses for NPK contents were made for each location. The effects of fertilizer treatments on the number of plants and ears ha^{-1} and grain and stalk yields were recorded and analyzed. The interaction of treatments and locations exhibited significant differences for all the parameters studied. Fertilizer treatments did not significantly affect the number of plants and ears at harvest at all locations. These treatments had significant effects on grain and stalk yields at three locations. At Bharakahu, both of these traits exhibited non-significant differences, while grain yield at Sihala and stalk yield at Rawat were not significantly affected by treatments. At all other locations the grain and stalk yields were significantly increased by increasing the amount of N and P fertilizer. The across locations means indicated that the highest grain and stalk yields were obtained in 80:30 and 80:60. For economic analysis, the variable costs, the total and net returns and marginal rate of returns were computed. The economic analysis indicated that the highest net income was obtained in 80-30 but it also increased the initial cost. The highest marginal rate of return was obtained in 80-0.

Key Words: NP fertilizers; Maize; Economic analysis; Farm inputs; *Zea mays*

INTRODUCTION

Maize (*Zea mays* L.) has attained the top most ranking in the world cereals both in terms of total production and per unit yield (FAO, 2003). In Pakistan, maize is the third most important cereal after wheat and rice. It is annually grown on about one million hectares of land with a total production of two million tonnes, and an average yield of two tonnes ha^{-1} (FAO, 2003). This yield level is roughly about 40% of the world average and 50% of the average in the Asia Pacific region (FAO, 2003). Since maize in Pakistan is grown in diverse ecologies, the yield levels vary considerably among the ecologies. The highest yielding maize is the spring crop in the plains of Punjab which is grown under the improved technologies and generally good quality hybrid seed is planted. On the other hand, the lowest yielding maize crop is in the rainfed areas, where generally low yielding local varieties are planted under traditional cultural practices. In ICT area, about 13,000 ha of maize is planted with an average yield of one ton ha^{-1} (Anonymous, 2003). There is a great need to increase yield of maize by introducing new inputs including fertilizers.

In spite of great yield potential of maize, the average maize yield is still very low in the country. Many factors like the lack of quality seed of improved varieties and hybrids, rainfall distribution and low soil fertility significantly contribute towards low yield. Among the various factors of crop production, fertilizers play a pivotal role. Though chemical fertilizers are still popular among farmers, because of the high costs their use is declining (Bakhsh *et al*., 2001). It is estimated that yield can be increased by 40-50% by means of balanced supply of fertilizers and improved N inputs under suitable conditions (Mihaila & Cracium, 1986; Sabbir *et al*., 1987; Bruce *et al*., 2002). A good variety can't express its yield potential if not judiciously fertilized. To maintain a sufficient net income, the farmer must optimize the use of nitrogen fertilizers (Bertin & Gallais, 2000).

Bhadari *et al*. (1986) reported that in 44 rainfed trials with maize/wheat cropping frequencies, application of 90 kg N + 30 kg P + 20 kg K ha^{-1} increased maize grain yields by 1.08 t ha^{-1} in the kharif season and 0.64 t ha^{-1} of wheat in the rabi season due to residual effect of NPK, and by 1.57 t when wheat was also given 80 kg N + 40 kg P ha^{-1}. Available N and P contents in the soils after harvest of crops were lower than without applied NPK. Concerted efforts have been made to improve the nitrogen efficacy by using fertilizers, their time of application, rates, methods and techniques (Tandon, 1987). Nitrogen stress is also reported to delay leaf appearance (White & Grace, 2000) while greater rates of phosphorus are reported to increase the leaf area (Szundy *et al*., 1997) which is an important contributing factor towards high grain and fodder yields. Supply of production inputs is one of the best methods to increase maize yield, particularly the adequate fertilizer application, as the maize crop needs an abundance of N and high levels of P and K (Deo, 1972).

Several studies have been conducted to determine the effect of chemical fertilizers (NPK) on yield and yield components of maize in Pakistan. However, most of the studies have been conducted at the research stations, and not many studies at the farmer's fields have been conducted. Also, the economic impact of these studies has been generally ignored. Keeping in view this shortcoming, the present study was conducted at the farmers fields to rationalize economic impact of different fertilizer combinations in improving maize production.

MATERIALS AND METHODS

The experiment was conducted at five different locations of Islamabad Capital Territory (ICT) for two years during kharif seasons of 1998 and 1999. The intention was to identify agronomic and economic responses of different fertilizer levels at the specified locations: Golra, Rawat, Thandapani, Sihala and Bharakahu. The experiment was conducted on silty-clay to loam soils having certain amounts of organic matter, $NaHCO_3$, soluble phosphorus and had a striated paste pH range of 7.3 to 9.2 in upper 15 cm and in lower 30 cm soil profile. An improved maize variety Gauher was planted with six NP levels/treatments (40:00, 40:30, 40:60, 80:00, 80:30 & 80:60 kg ha^{-1}). The harvested plant population ranged from 52,200 to 55,100 ha^{-1}. After making possible combinations, these were randomized in a complete block design with three replications in 75 cm apart rows, in a plot size of 5 × 3 m. Nitrogen and phosphorus were applied at sowing in the form of urea and single super phosphate (SSP), respectively. The crop was harvested from a net plot size of 5 × 1.5 m at the end of September each year. Soil analyses were carried out for all the locations in both years. Data for number of ears ha^{-1}, plants harvested (ha^{-1}), stalk yield (t ha^{-1}), grain yield at 15% moisture contents (kg ha^{-1}) were recorded. Cost benefit ratio was calculated on the grain and stover yields ha^{-1} at 15% moisture content basis. The data recorded were statistically analyzed and analyses of variance were computed for all treatments. The data were also subjected to economic analysis by calculating MMR (%) using variable costs.

RESULTS AND DISCUSSION

During the experimental period in 1999, more rainfall (309 mm) was received. This ultimately lowered the temperature from 32.0 to 31.2°C, and relative humidity remained high. Because of high rainfall, soil moisture at 20 and 30 cm soil depths was higher during the said year.

Soil analysis of sites showed that N contents were very low at all the locations (Table I). Other fertility components (P & K) were recorded as the highest at Rawat (12.0 & 4.9 ppm for P, and 163 and 117 ppm for K) at both depth levels (15 and 30 cm), respectively. P and K contents at 15 cm depth at Bharakahu and Golra were at par, with each other while they were significantly lower at Thandapani and Sihala. At 30 cm depth, significantly higher P and K contents were recorded at Sihala followed by Thandapani. These contents at Golra and Bharakahu remained at par with each other (Table I).

In the year 1998, T_2 and T_4 (40:30 and 80:00 NP) produced maximum number of plants and ears ha^{-1} (58,300 and 56,600, respectively) at Golra (Table III & IV), whereas, stalk yield of 11,700 kg ha^{-1} (Table II) at this location was brought about by T_5 (80:30 NP). In 1999 this site again produced highest number of plants (57,000) under T_1 (40:00 NP) while with T_4 highest number of plants (59,000) were recorded at Sihala in the said year (Table III). In spite of different soil characteristics, T_4 appeared as the most leading treatment for producing number of plants ha^{-1} in both years (Table III), which ultimately increased number of ears (Table IV). T_5 and T_6 produced equal stalk yields (13.0 t ha^{-1}) in the year 1998, whereas in 1999, under these treatments stalk yield was 13.3 and 13.7 t ha^{-1}, respectively (Table II). T_6 (80:60 NP) gave the highest grain yield ha^{-1} (Table V) in both years, followed by T_4 (80:00). Increase in N and P rates increased number of plants, ears and grain yield. These results are in agreement with those of Goring & Thein (1979). Treatments vs. locations expressed significant difference in all the biological parameters. Such type of data presentation creates a mess to all concerned, thus to solve this paradox, mean values were computed. This type of data computation and presentation is also reported by Hayee *et al*. (1989) and Smad (1992).

In the year 1998 and 1999, T_5 and T_6 earned net returns amounting to Rs. 20,791 and Rs. 21,812, respectively. The marginal rate of returns (MRR) in these years remained high with T_4 and is known as the most economical variable cost indicator (Table V). These results are in conformity with the findings of Kasana and Ropal (1983), Rauf and Aslam (1983) and Brattan and Truscatt (1988). The system was found to sustain an increase in maize yield by over 60%, reduced the use of N fertilizer and gave an attractive net income and MRR per unit cost. It gave a reasonable benefit cost ratio of 1.23 to 1.32 and looks promising for maize production in the tropical areas, increased with enhanced N application but were relatively unaffected by P. However, both N and P increase grain N and P uptake to the interaction of biological and technological innovations adopted by the farmer. One of the important determinants of high ear yield on the research farm was increase in the fertilizer use. The fertilizer is one such vital input, the price of which has been under control in one form or the other. This has lowered down to ensure that

Table I. Soil analyses showing the concentrations (ppm) of N, P & K at different depths at all the locations

Treatments		Locations					Mean
		Golra	Rawat	Thandapani	Sihala	Barakahu	
15 cm	N	0.097	NR*	0.130	0.13	0.10	0.11
	P	10.40	12.00	10.20	10.20	10.60	10.68
	K	93.60	163.80	62.40	62.40	98.30	96.10
30 cm	N	0.07	NR*	0.10	0.10	0.06	0.08
	P	3.00	4.90	10.60	20.00	3.00	8.30
	K	85.80	117.00	98.30	109.20	82.70	98.60

* Not recorded.

Table II. Location wise effect of NP fertilizer levels on number of maize plants harvested during 1998 and 1999 ("000" plants ha^{-1})

Tr. No.	Treatments		Locations					
			Golra	Rawat	Thandapani	Sihala	Bharakahu	Mean
	N	P			1998			
1	40	00	52.80	51.30	53.90	57.20	45.10	52.06
2	40	30	49.60	57.60	49.60	54.70	52.80	52.86
3	40	60	58.30	54.10	50.40	50.30	48.70	52.36
4	80	00	53.10	54.40	52.70	55.30	51.90	53.48
5	80	30	49.70	53.30	53.70	57.10	44.90	51.74
6	80	60	53.20	51.80	56.10	54.40	44.40	51.98
					1999			
1	40	00	57.7	56.5	51.2	55.1	48.7	53.84
2	40	30	53.5	54.8	48.0	52.7	52.2	52.24
3	40	60	56.5	58.0	52.0	51.9	49.6	53.60
4	80	00	56.8	56.7	55.3	59.0	47.8	55.12
5	80	30	56.2	57.5	50.0	58.1	49.8	54.32
6	80	60	57.5	55.2	55.8	57.2	46.9	54.52
LSD (α = 0.05)			NS	NS	NS	NS	NS	
CV (%)			6.3	7.6	9.8	10.4	7.8	

Table III. Effect of NP fertilizers on number of ears in maize during 1998 and 1999 ("000" ears ha^{-1})

Treatment No.	Treatments		Locations					Mean
			Golra	Rawat	Thandapani	Sihala	Barakahu	
	N	P			1998			
1	40	0	50.10	49.40	51.10	54.30	36.20	48.22
2	40	30	45.70	45.60	53.00	49.70	48.30	48.46
3	40	60	54.90	49.80	51.20	48.40	48.90	50.64
4	80	00	56.60	49.90	47.80	58.80	50.70	52.76
5	80	30	61.60	48.70	50.50	57.20	44.40	52.48
6	80	60	52.50	47.30	57.20	54.80	52.70	52.90
					1999			
1	40	00	56.8	55.2	49.0	49.9	43.1	50.80
2	40	30	55.2	51.7	47.8	51.6	49.6	51.18
3	40	60	57.5	51.7	48.2	50.0	48.0	51.08
4	80	00	57.2	53.3	52.5	54.8	46.7	52.90
5	80	30	57.3	54.3	48.0	54.2	47.1	52.18
6	80	60	60.0	53.5	55.7	57.2	47.8	54.84
LSD (α = 0.05)			NS	NS	NS	NS	NS	NS
CV (%)			6.2	10.4	10	10	13	7.3

Table IV. Location wise effect of NP fertilizer levels on maize grain yield during 1998 and 1999 (kg ha^{-1})

Tr. No.	Treatments		Locations					Mean
			Golra	Rawat	Thandapani	Sihala	Barakahu	
	N	P			1998			
1	40	00	4337	4572	3351	2710	2208	3436
2	40	30	4238	4781	3632	2922	3061	3729
3	40	60	4667	4221	3834	3607	3092	3884
4	80	00	4762	4465	3688	3290	3245	3850
5	80	30	4796	4493	4002	3651	3619	4112
6	80	60	4624	4493	4350	3675	3774	4183
					1999			
1	40	00	3913	4067	3210	2490	2630	3262
2	40	30	4567	4551	3304	2722	3005	3628
3	40	60	5058	4761	3555	2895	3128	3879
4	80	00	5346	4998	3649	2981	3087	4012
5	80	30	5522	5022	3819	3225	3107	4139
6	80	60	5193	5108	4682	3246	3198	4285
LSD (α = 0.05)			1053	743	821	NS	NS	NS
CV (%)			12.6	8.72	9.16	10.6	13.8	

Table V. Effect of NP fertilizer levels on maize stalk yield during 1998 and 1999 (Tonnes ha^{-1})

Tr. No.	Treatments		Locations					Mean
			Golra	Rawat	Thandapani	Sihala	Barakahu	
	N	P			1998			
1	40	00	12.3	19.3	10.9	10.7	11.1	12.9
2	40	30	11.2	19.5	10.3	10.4	11.1	12.5
3	40	60	12.2	18.4	11.3	8.5	11.9	12.5
4	80	00	12.0	17.8	11.6	11.4	11.0	12.8
5	80	30	12.9	18.2	12.4	11.9	11.3	13.3
6	80	60	11.5	18.2	12.3	13.6	12.9	13.6
					1999			
1	40	00	13.1	14.3	12.0	10.6	10.4	12.8
2	40	30	13.5	14.6	12.2	11.2	9.8	12.3
3	40	60	14.2	14.3	13.1	12.1	10.6	12.9
4	80	00	15.6	15.0	13.6	13.4	11.2	13.8
5	80	30	16.3	15.7	13.8	14.5	11.4	14.3
6	80	60	16.6	15.2	15.1	14.8	11.8	14.5
LSD (α = 0.05)			2.3	NS	2.6	3.3	NS	
CV (%)			6.2	10.4	10.0	13.0	7.3	

Table VI. Economic analysis of effect of NP fertilizer levels on maize production

Variables	Farmers	Treatments				
		80-0	40-30	80-30	40-60	80-60
Grains (kg)	3349	3,931	3,678	4,125	3,881	4,234
Income (Rs)	23443	27,517	25,746	28,875	27,167	29,638
Stalks (t)	12.9	13.3	12.4	13.8	12.7	14.1
Income (Rs)	6450	6,650	6,200	6,900	6,350	7,050
Total income (Rs)	29,893	34,167	31,946	35,775	33,517	36,688
Variable cost (Rs)	739	1,478	1,887	2,626	3,035	3,774
Net income (Rs)	29154	32,689	30,059	33,149	30,482	32,914
Increase over farmer's practice (%)	-	12.13	3.10	13.70	4.56	12.90
MRR (%)	-	478.35	D	40.07	D	D

Grains = Rs. 7/kg; Stalks = Rs. 500/t; Urea = Rs. 425/bag; DAP = Rs.880/bag

the economics of fertilizer use is not unduly affected by escalation in the price of fertilizer to the farmer.

Gunvant (1986) investigated that adoption of correct methodologies supplemented by correct economic practices would increase efficiency of fertilizer use and thus raise return on it as it gave profit amounting to Rs. 426 million. Nagy (1983) found that technological improvements during 1945-64 gave profit of FT 704 t^{-1} for wheat and FT 517 t^{-1} for maize. Profits of FT 28 t^{-1} for wheat and FT 22 t^{-1} for maize for every FT 100 t^{-1} of production costs increase were also recorded. Chiao (1986) reported that maize farmers were ahead of others in acquiring mean cultivation techniques, and are benefited more than rice or cotton growers. Ogungbile and Dogunde (1986) found that 100 kg N ha^{-1} is optimum for 24-72 thousand plants ha^{-1} in both locations, with nitrogen costs varying from N 1.02 to N 3.02 kg^{-1} plant cost from N 1.25 to N 1.75 per thousand plants and maize selling price. Fixed at N 0.25 kg^{-1}, the predicted amount of nitrogen and number of plants ha^{-1} maximized profit per hectare, and between 48.2 and 55.2 thousand plants ha^{-1}. Himayatullah (1990) reported that as a result of substantial increase in yield ha^{-1}, the use of fertilizer is one of the quickest and economical means for increasing agricultural production.

The maximum benefit over check was obtained by the level 80-30 (14%), followed by the NP levels 80-60 (13%) and 80-0 (12%) (Table VI). Marginal rate of return (MRR) was 478% in 80-0 and 40% in 80-30. Other treatments gave more yield but due to higher cost of fertilizer levels involved, MRR were negative i.e. dominance. The MRR for the level 80-30 was very low and not acceptable. Also the additional cost of Rs. 1148 for 80-30 over 80-0 was beyond the reach of the farmers of the area. The increase in level of fertilizer had positive effect on yields but involved higher initial costs.

Keeping in view the socio-economic conditions of the farmers in the area and subsistence nature of the crop, it is imperative to consider cost of production as an important factor in the introduction of technological inputs. With the highest MRR and acceptable increase in yields, the fertilizer level 80-0 got the first priority.

Fertilizers are thus a major factor in a package of improved farm inputs and practices. The average consumption of fertilizer has also increased from 5 kg ha^{-1} in 1965-66 to 63 kg and 87 kg ha^{-1} in 1884-85 and 1986-87, respectively (Marwat, 1986). Variation in yield leading to variation in net returns was due to different agro-climatic conditions. Our studies clearly indicate that the application of nitrogenous fertilizer alone at a rate of 80 kg ha^{-1} is the most economic option for a maize grower in the rainfed areas of Islamabad and other regions with similar agro-ecological conditions.

These results are not the final words but will help a lot while formulating recommendations for enhancing maize production, especially under agro-climatic conditions of ICT.

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