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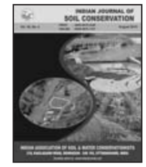

Effect of integrated nutrient management on growth, yield and quality of maize (*Zea mays* L.) in temperate conditions

Uzma Bashir[1], Tahir Ali and Fozia Qureshi

Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar -191121, Jammu and Kashmir.
[1]E-mail: druzmass@gmail.com

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ABSTRACT

A field experiment was carried out for two consecutive *kharif* seasons of 2006 and 2007 on silty clay loam (6.8 pH, organic carbon 0.91% and available N, P and K of 236.06, 15.56 and 184.46 kg ha^{-1}, respectively) to study the effect of inorganic fertilizers, organic manure and biofertilizers on growth, yield attributes, yield and quality of maize (*Zea mays* L.). There was positive and significant increase in the leaf area index (7.03%), cob length (50.5%), grain row cob^{-1} (41.73%), grains row^{-1} (19.73%), grains cob^{-1} (14.44%), 1000 grain weight (2.21%), cob girth (19.50), grain yield (23.78%), stover yield (19.63%), protein (20.31%) and starch content (14.71%) of maize with increase in the levels of inorganic fertilizers from 60 to 100% of recommended dose of NPKZn. Application of 30 t FYM ha^{-1} had a favorable and significant effect on growth, yield attributes, yield, quality and total N, P and K uptake. Dual inoculation of seed with *Azotobacter* + *Phosphorus Solubilizing Bacteria (PSB)* also showed similar results.

1. INTRODUCTION

Among different food grains, maize is a staple food of millions of people all over the world. National productivity of maize is about 1.7 t ha^{-1} against world average of about 4.2 t ha^{-1}. National contribution of maize to the food grain production is 21.75 Mt from an area of 8.70 m ha (Anonymous, 2012). Maize is an important crop of Jammu and Kashmir state and is second after rice grown over the area of 0.31 m ha with an average productivity of 15.66 q ha^{-1} (Anonymous, 2010).

Maize, being an exhaustive crop, depletes a major portion of plant nutrients from soil unless the soils are supplied with nutrients removed by the crop. Use of chemical fertilizers cannot be avoided completely since they are the potential sources of high amount of nutrients in easily available forms. Most of the crops respond quickly to chemical fertilizers and give higher yield maize is more responsive. At the same time, application of organic manure alone does not produce required yields due to low nutrient status. Sustainable yield levels could be achieved only by applying appropriate combination of organic manure and chemical fertilizers. The balanced fertilization is the quickest way of boosting crop production though it can be achieved through balanced application of fertilizers along with organic resources and more and more accurately and precisely through INM (Karki *et al.,* 2005). Integrated nutrient management (INM) which is one of the most important components of the agricultural production system to sustain higher crop yields *vis-à-vis* organic and inorganic sources, is maintaining soil health. The interactive advantage of combining organic and inorganic sources of nutrients in integrated nutrient management have shown additive effect in comparison to the use of each component separately (Palaniappan and Annaduari, 2007). The results emanating from fertilizer experiments have clearly indicated that imbalanced use of chemical fertilizers has resulted in numerous problems (Sharma and Subehia, 2003). Keeping these points in view, the present study was executed to evaluate the integrated nutrient use on growth, yield and quality of maize.

2. MATERIALS AND METHODS

A field experiment was carried out at Experimental Farm Division of Soil Science, Sher-e-Kashmir University of Agricultural Sciences and Technology (K), Shalimar which lies between 340°.8/ N latitude and 74°.83 / E longitude at an altitude of 1587 m amsl. The climate at the experimental area is temperate with mild summer and cold winters, with a wide variation in the maximum and minimum temperatures. Meteorological data for the experimental period indicate that total rainfall received during crop season of 2006 and 2007 was 7.591 and 2.843 cm, respectively. Mean maximum temperature was 27.12 and 27.48°C and mean minimum temperature was 12.73 and 12.87°C, respectively during the two cropping seasons.

The soil was silty clay loam in texture with pH 6.80, organic carbon 0.91% and available N 236.06, P 15.56, K 184.46 kg ha^{-1} and C.E.C 11.93 [cmol (p^+) kg^{-1}], respectively. The treatments consist of three levels of inorganic fertilizers-100, 80 and 60% of recommended dose of fertilizer comprising of (90:60:30:20; 72:48:24:16; 54:36:18:12 of N : P_2O_5: K_2O : $ZnSO_4$ kg ha^{-1}), with three levels of organic manure (10, 20 and 30 t FYM ha^{-1}) and two levels of bio fertilizers sun inoculated and inoculated with *Azotobacter (Azotobacter chrococcum)* and *Phosphorus Solubilizing Bacteria (PSB) Bacillus Megaterium* var. *phosphaticum* @ 50 g kg^{-1} seed each) and were laid out in factorial randomized block design with three replications and were applied during both the cropping seasons, respectively.

Farm yard manure was applied as basal dose 15 days prior to sowing as per the treatment combination and incorporated into the soil. Urea, single super phosphate and muriate of potash were used as a source of inorganic fertilizers. The total quantity of phosphorus, potassium and zinc and one third of nitrogen was band placed just before sowing. The rest of the nitrogen was top dressed into two equal splits at the knee hight and teaseling stage. Maize variety "Cv-C_6" was sown on 29th May, 2006 and 19th April, 2007 and harvested on 30th September, 2006 and 30th August, 2007. The plot size was 2.4 x 4.2 m and crop was sown at a spacing of 60 cm row to row and 20 cm plant to plant. Thinning was done 25 days after sowing to keep required plant population. The leaves from the plant of marked rows were counted and average number of leaves per plant was calculated. The length and breadth of 20 randomly selected leaves from each plot was measured *in-situ* to ascertain the average pseudo leaf area from each plot. Pseudo leaf was multiplied by adjustment factor 'C' and actual leaf area was determined. The adjustment factor 'C' was calculated as follows:

$$C = \frac{\text{Actual leaf area}}{\text{Pseudo leaf area}}$$

The actual leaf area of the sample selected for calculation of adjustment factor was determined by leaf area meter (C1-251 systronic area meter), and pseudo leaf area of the sample was also ascertained. Leaf area index (LAI) was calculated by using the following formula Watson (1947):

$$LAI = \frac{\text{Total leaf area per unit area}}{\text{Land area per unit area}}$$

Data were recorded on cob length, grain rows cob^{-1}, grains row^{-1}, grains cob^{-1}, 1000 grain weight and cob girth. Cobs from randomly selected five plants were removed and their length was measured in cm and then was averaged. Grain rows in each cob was counted and then averaged to calculate rows cob^{-1}. Grains row^{-1} was counted in five cobs and was averaged to get grains per row data. Cob girth was measured with the help of a vernier calliper from top, middle and bottom portions. Thousand grains were counted at random from each treatment and weighed at 12% moisture content. The crop was harvested at 75% silking. The crop from each plot was harvested and weighed in kg $plot^{-1}$ and converted to q ha^{-1}.

Protein content in grains was determined by multiplying the total nitrogen content by empirical factor 6.25 Mckenzie and Wallace (1954). Starch content was estimated by anthrone reagent method as described by Clegg (1956). Uptake of N, P and K was computed by multiplying corresponding yields of crop and the percent N (Macro kjeldhal method Jackson, 1967), P by (Vanadomolybdate method Jackson, 1973) and K (Flame Photometer method Toth and Prince, 1948) concentration in grain and stover, Data obtained in respect of observations were statistically analyzed using MINITAB (version 14).

3. RESULTS AND DISCUSSION

Growth and Yield Attributing Characters

Growth

Leaf Area Index (LAI) increased significantly with the increase in the doses of recommended inorganic fertilizers from 60 to 100% (Table 1). Pronounced effect of 100% recommended inorganic fertilizers application on LAI was attributed to adequate and continuous supply of nutrients which results in increased leaf area index. However, Kumar and Walia (2003) and Sutaliya and Singh (2005) found an increase in leaf area index of maize crop with the application of N up to 175 kg ha^{-1}. Organic manure significantly increased the leaf area index. Application of FYM up to 30 t ha^{-1} (Table 1) recorded significant increase in LAI as compared to lower doses which may be due to the fact that organic manures supply the nutrients in balanced proportion, which might have affected the crop synergistically resulting in increase in LAI (Jayaprakash *et al.,* 2003). Leaf area index showed significant improvement with *Azotobacter* and *PSB* inoculation over no inoculation (Table 1). Earlier Balyan *et al*. (2006) also reported a significant impact of biofertilizers on LAI of maize.

Yield parameters

Maximum yield attributing characters (Table 1) like cob length (16.06 cm), grain row cob^{-1} (17.83), grain row^{-1} (30.82), grain cob^{-1} (447.89), 1000 grain weight (236.14 g) and cob girth (13.00 cm) showed significant difference with the application of 100% recommended inorganic fertilizer. The increase in yield attributes of maize could be ascribed to overall improvement in crop growth enabling the plant to absorb more nutrients as it is evident from the enhanced vegetative growth and uptake of nutrients which empowered as a result of higher accumulation of photosynthesis in reproductive parts. Such effects are reflected as grains per cob and 1000 grain weight. The results are in conformity with those of Singh and Totawar (2002) and Abdul Kadir *et al. (*2002) who observed significant increase in yield attributes with increase in the levels of recommended inorganic fertilizers up to 100%.

It was observed that yield attributing characters increased significantly by application of FYM from 10 to 30 t ha^{-1} (Table 1). Addition of FYM improved physical, chemical and biological properties of soil. This might have promoted root growth leading to higher nutrient extraction from the soil and translocation to aerial parts of the plant and finally to the reproductive parts. Seed inoculation with *Azotobacter* and *PSB* significantly increased the yield contributing characters as compared to control (Table 1). It could be attributed to improvement in nutritional status of the soil and creation of congenial environment for better root growth through secretion of growth promoting substances (gibberellin, cytokinin and auxin) and availability of nitrogen fixed by microorganism leading to enhanced translocation to reproductive structure. These results are in accordance with Sawarkar (2005) who also observed maximum maize yield of 38.35 q ha^{-1}.

Yield and Quality Parameters

Grain yield

There was a significant increase in grain yield of maize with increase in fertility levels from 60 to 100% of recommended levels of inorganic fertilizer (Table 2). Maximum grain yield (72.60 q ha^{-1}) was recorded with the application of 100% recommended inorganic fertilizers. Higher grain yield with increasing fertility levels may be attributed to the higher synthesis and partioning of metabolites into economic part. The results are also in conformity with those of Banerjee *et al.* (2006) and Brar *et al.* (2006), who also reported significant increase in grain yield of maize with increase in levels of inorganic

Table: 1
Growth and yield attributes of maize as affected by integrated nutrient management (pooled data of 2 years)

Treatment	Leaf area index	Cob length (cm)	Grain row cob^{-1}	Grain row^{-1}	Grain cob^{-1}	1000 grain weight (g)	Cob girth (cm)
Recommended inorganic fertilizers (%)							
60 N P K Zn	4.12	10.67	12.58	25.74	391.35	231.03	10.87
80 N P K Zn	4.28	13.57	15.50	28.47	433.21	233.42	11.71
100 N P K Zn	4.41	16.06	17.83	30.82	447.89	236.14	13.00
SEd±	0.02	0.89	0.77	0.80	4.34	0.29	0.06
LSD (0.05)	0.04	1.80	1.56	1.64	8.83	0.60	0.14
Organic manure (t ha^{-1})							
10 FYM	4.22	10.08	12.01	24.93	396.45	230.25	10.49
20 FYM	4.25	13.34	15.18	28.46	420.22	233.44	11.66
30 FYM	4.35	16.78	18.71	31.46	455.79	236.89	13.42
SEd±	0.02	0.89	0.77	0.80	4.34	0.29	0.06
LSD (0.05)	0.04	1.80	1.56	1.64	8.83	0.60	0.14
Biofertilizers (50 g kg^{-1} seed)							
Control	4.24	11.37	13.33	26.37	410.35	231.51	10.95
Azotobacter + PSB	4.30	15.42	17.28	30.32	437.95	235.55	12.77
SEd±	0.01	0.81	0.72	0.74	3.54	0.24	0.05
LSD (0.05)	0.03	1.66	1.46	1.52	7.21	0.49	0.11

60% NPKZn=54:36:18:12 kg ha^{-1} ; 80% NPKZn= 72:48:24:16 kg ha^{-1} ; 100%= 90:60:30:20 kg ha^{-1}

fertilizers. Higher grain yield (76.54 q ha^{-1}) of maize was obtained with the application of 30 t FYM ha^{-1}. Mehta *et al.* (2005) also reported similar findings. Inoculation with *Azotobacter* and *PSB* recorded 7.99% increase in grain yield over control. Similar findings in terms of grain yield have also been reported by Subba Rao (2000) and Mali and Gupta (2000).

Stover yield

Two years study revealed that stover yield increased from 85.55 q ha^{-1} in 60% of recommended inorganic fertilizer to 102.35 q ha^{-1} with the application of 100% of recommended inorganic fertilizers (Table 2). Increase in stover yield of maize may be attributed to higher leaf area index. Similar line of work has been reported by Jayaprakesh *et al.* (2003). Application of 30 t FYM ha^{-1} produced 101.24 q ha^{-1} stover yield. The corresponding values for 20 and 10 t FYM ha^{-1} were 92.08 and 85.31 q ha^{-1}, respectively. Similar results were also earlier reported by Kumpawat and Jat (2005). *Azotobacter* and *PSB* recorded 7.13% increase in stover yield over no inoculation. PSB are broad spectrum biofertilizers which may increase the yield by 10 to 30% and supplement phosphorus need by 30 kg P_2O_5 (Tilak, 1998).

Protein content

Application of 100% of recommended inorganic fertilizer recorded significantly higher protein content in grain and the magnitude of significant increase in protein content was 20.31 and 7.74% over 80 and 60% of recommended inorganic fertilizer as given in Table 2. Nanjundappa and Manure (2002) also reported similar findings. Protein content was maximum under 30 t FYM ha^{-1} followed by 20 and 10 t ha^{-1}. Similar findings are reported by Kumari and Singaram 1996. Inoculation with *Azotobacter* and *PSB* increased the protein content in grain and the magnitude of increase was 7.81% over no inoculation.

Starch content

There was a positive increase in the starch content with the increase in the levels of recommended inorganic fertilizers (Table 2), which results in better vegetative growth, increases in photosynthesis assimilation of more carbohydrates which has a greater impact on starch content. Application of 30 t FYM ha^{-1} recorded significantly higher starch content of (50.46%) as compared to 48.81 and 46.72% at 20 and 10 t FYM ha^{-1}, respectively. The effect of biofertilizers was not significant.

Nitrogen, Phosphorus and Potassium Uptake

Recommended inorganic fertilizer, organic manure and biofertilizers had a favourable and significant effect on total nitrogen, phosphorus and potassium uptake by biological produce (Table-3). The maximum total nitrogen, phosphorus and potassium uptake was 164.26, 49.00 and 183.19 kg ha^{-1}, respectively with the application of 100% of recommended inorganic fertilizer as compared to 80 and

Table: 2

Effect of integrated nutrient management on yield and the quality of maize (pooled data of 2 years)

Treatment	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Protein (%)	Starch (%)
Recommended inorganic fertilizers (%)				
60 N P K Zn	58.65	85.55	7.63	45.20
80 N P K Zn	66.00	90.73	8.52	48.94
100 N P K Zn	72.60	102.35	9.18	51.85
SEd±	2.19	2.09	0.30	0.17
LSD (0.05)	4.45	4.25	0.62	0.34
Organic manure (t ha^{-1})				
10 FYM	56.00	85.31	7.94	46.72
20 FYM	65.00	92.08	8.47	48..81
30 FYM	76.54	101.24	9.00	50.46
SEd±	2.19	2.09	0.30	0.17
LSD (0.05)	4.45	4.25	0.62	0.34
Biofertilizers (50 g kg^{-1} seed)				
Control	63.13	89.67	8.19	48.64
Azotobacter + PSB	68.18	96.07	8.83	48.68
SEd±	0.61	0.96	0.24	0.03
LSD (0.05)	1.24	1.96	0.50	N.S

60% NPKZn=54:36:18:12 kg ha^{-1} ;80% NPKZn= 72:48:24:16 kg ha^{-1} ; 100%= 90:60:30:20 kg ha^{-1}

Table: 3
Effect of integrated nutrient management on total nutrient uptake (kg ha^{-1}) by maize (pooled data of 2 years)

Treatment	Total uptake by Biological Produce (kg ha^{-1})		
	Nitrogen	Phosphorus	Potassium
Recommended inorganic fertilizers (%)			
60 N P K Zn	102.38	24.00	115.63
80 N P K Zn	133.12	38.00	143.47
100 N P K Zn	164.26	49.00	183.19
SEd±	10.35	2.77	6.80
LSD (0.05)	21.05	5.63	13.80
Organic manure (t ha^{-1})			
10 FYM	104.83	23.13	122.67
20 FYM	129.54	36.65	145.76
30 FYM	165.40	50.00	173.85
SEd±	10.35	2.77	6.80
LSD (0.05)	21.05	5.63	13.80
Biofertilizers (50 g kg^{-1} seed)			
Control	125.24	33.01	149.34
Azotobacter + PSB	141.37	40.43	155.51
SEd±	7.13	2.53	3.24
LSD (0.05)	14.50	5.14	N.S

60% NPKZn =54:36:18:12 kg ha^{-1}; 80% NPKZn = 72:48:24:16 kg ha^{-1} ; 100%= 90:60:30:20 kg ha^{-1}

Note: 20 kg zinc is too high because in temperate conditions there is high zinc absorption capacity and lower availability and that is why we apply more quantity of zinc in these soils

60% of recommended inorganic fertilizers. Organic manure significantly increased the total nitrogen, phosphorus and potassium uptake upto 30 t FYM ha^{-1} (Table 3). This was perhaps due to continuous supply of nitrogen, phosphorus and potassium throughout the crop growth as the nutrients from inorganic sources were available to the crop in the early stage. A similar trend with respect to effect of INM on nutrient content and uptake of rice was reported by Shanmugam and Verraputtiram (2000). *Azotobacter* and *PSB* application significantly increased the total nitrogen and phosphorus uptake. However, effect of the biofertilizers on total potassium uptake was significantly non significant at harvest.

4. CONCLUSIONS

The study concludes that application of recommended inorganic fertilizers, FYM and bio-inoculants significantly improved growth, yield attributes, yield and quality of maize. The application of 100% of recommended inorganic fertilizers with 30 t FYM ha^{-1}, respectively and dual seed inoculation with *Azotobactor* and *PSB* improved the LAI, yield attributing characters and quality of maize which may be recommended for the temperate conditions of Kashmir valley.

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