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RESEARCH PAPER

Effect evaluation of balanced fertilizer use in maize (*Zea mayz* L.) through yield attributes, crop efficiency and energy relationships in subtropical floodplain soils

PRITPAL SINGH, SAT PAL SAINI* AND AMANDEEP SINGH SIDHU
Krishi Vigyan Kendra (PAU), Haveli Kalan, ROPAR (PUNJAB) INDIA
(Email : gahuniasp1962@gmail.com)

Abstract : The balanced use of fertilizers is important for achieving economically optimal crop yield. Therefore, a field experiment at 5 different on-farm (farmer's field) locations were conducted during *Kharif*-2010 to assess the effect of balanced fertilizer use in maize (*Zea mayz* L.) grown in maize-wheat cropping sequence in an irrigated subtropical floodplain soils. The fertilizer treatments thus replicated at different locations includes 100 per cent NPK (T_1), 100 per cent NPK+30.0 kg S ha^{-1} (T_2), farmers' practice (FP) of fertilizer application (T_3), FP+30.0 kg K_2O ha^{-1} (T_4), FP+ 30.0 kg S ha^{-1} (T_5) and FP+30.0 kg K_2O ha^{-1} +30.0 kg S ha^{-1} (T_6) to investigate their effect on yield, yield attributes, crop efficiency and energy relationships associated with fertilizer application. The results revealed significantly ($p=0.05$) higher plant height, cob length, test weight (1000-grain weight) and maize grain yield in T_2 plots as compared to either of compared treatment. The plots receiving 100 per centNPK (T_1) yielded 19.1 per cent higher maize grain yield than T_3, however, the yield difference was 28.0 per cent when T_3 was compared with T_2, demarcating the synergistic effect of S application to maize. Even, the maize yield in FP plots (T_6) receiving S and K application coupled with >60 per cent higher NP application rate than 100 per cent NPK was 11.9 per cent lower than T_2 plots, emphasizing the need of N application at maize sowing that farmer's generally omit. The energy relationships associated with fertilizer application revealed total output energy of 133.8 x 10^3 MJ ha^{-1} in T_2 plots as compared to 104.5 x 10^3 MJ ha^{-1} in FP (T_3) plots, with 4.9 x 10^3 MJ ha^{-1} higher use of total input energy in FP plots than T_2 plots. The energy use efficiency (15.6) and energy productivity (0.625 kg MJ^{-1}) further exhibited higher response in T_2 plots as compared to either of the compared treatment. The production efficiency also exhibited similar trend to that of maize yield and exhibited highest in T_2 (50.8 kg ha^{-1} d^{-1}) and lowest in T_3 (39.7 kg ha^{-1} d^{-1}). The economics of fertilizer application assessed through average gross and net-returns and economic efficiency further demarcates the credibility of balanced fertilizer application in maize. Present results thus summarized that application of S conjointly with 100 per cent NPK application favours plant growth and thereby ensures highest economic maize yield with low energy input.

Key Words : Economic efficiency, Input-output energy, Production efficiency, Yield attributes

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INTRODUCTION

Farmer's generally confined themselves to nitrogen (N) and phosphorus (P) application and skips sulphur (S) and potassium (K) application in crop production, and therefore, had to face economic loss due to reduction in crop yield. Among the major elements, K has been reported to be the most crucial for normal plant growth, since it has been playing a vital role in various metabolic activities *viz.,* photosynthesis, carbohydrates, starch formation and enabling crop plant to develop tolerance to drought conditions besides enhancing plant ability to resist attack of pest and diseases. It is been reported to be absorbed by plants in large amount than any other element (Brady, 1990) and plays an important role in increasing crop yield and improving the product quality (Mengel and Kirby, 1987). According to Saha *et al.* (2010)

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* **Author for correspondence.**

since K application effects on vegetative crop growth are not very clear and further since K-fertilizers are more costly than N fertilizer, and sometimes they are not available in the local market, its use at farmers' fields is low. Among secondary nutrients, S has been the most important, since more than 40 crops including cereals, pulses and legumes have been observed to respond S application in S-deficient Indian soils (Tandon, 1995). The periodic assessment of extent of S deficiency in Indian soils revealed that only 130 districts were suffering with varying degree of S deficiency during early 90's, that has now been increased to over 250 districts (Tandon and Massick, 2007). In the floodplain areas of Ropar (Punjab), maize-wheat is the second most predominant single year cropping system after rice-wheat, which has been in practice since last many years. In these areas, the flood water particularly during *monsoon* season brings sediments of varying chemical nature, which dictates the nutrient availability reactions in the soils (Singh and Singh, 2007). Among cereals, maize (*Zea mays* L.) has been the most important crop grown for fodder and grains and ranks 3rd after wheat and rice in the world (David and Adams, 1985) and has been the exhaustive crop having higher potential than other cereals and absorbs large quantity of nutrients from the soil during different growth stages (Edomwonyi and Egberanwen, 2009; Masood *et al*., 2011). According to He *et al.* (2008) continuous maize-wheat cropping without balanced and efficient use of fertilizers has been contributing towards losses in crop yield and profit margin. It has been observed that maize fail to produce good grain in plots without adequate nutrient application (Adediran and Banjoko, 2003). In the sub-humid Zimbabwe, partial decline in soil fertility and crop productivity at smallholder farms has been referred to be the result of continuous maize (*Zea mays* L.) production (Jeranyama *et al*., 2007). Therefore, it becomes important to investigate the effect of balanced fertilizer use on maize yield and further its assessment through different yield attributes, crop efficiency parameters and energy relationships so as prepare a balanced sheet for comparing applicability of balanced fertilizer use in comparison to farmer's practice (FP) of fertilizer application.

MATERIALS AND METHODS

Experimental site and soil characteristics:

The field experiment was conducted at five different farmer's field locations in Ropar (Roop Nagar) district of Indian Punjab during *Kharif*-2010. The experimental sites in Rasidpur (S_1, S_2), Asalatpur (S_3, S_4) and Wajidpur (S_5) villages of District (Fig. A) are situated along-side '*Satluj*' River, originating from 'Great Himalayas'. The experimental sites are located on the banks of active river channel receiving material of varying physico-chemical characteristics during each course of inundation that had a significant bearing on nutrient availability to crop plants (Singh and Singh, 2007). The climate of the area is typically a semiarid and subtropical characterized by hot summer with mean maximum temperature ($T_{max.}$) of 37.9^{0}C in May-June and cool winter with mean minimum temperature ($T_{min.}$) of around 6.0^{0}C in December-January (Fig. B). The average annual rainfall in the study area varied from 650-1300 mm of which about 75-80 per cent occurred during summer season from July to September and rest during the winter season. The year-around rainfall pattern of the experimental area has been shown in Fig. B. The variation in relative humidity (36.3-93.7%) in the experimental area throughout the year has been shown in Fig. B, demarcating a peak during July-August, the days when '*monsoon*' in the area is on full swing.

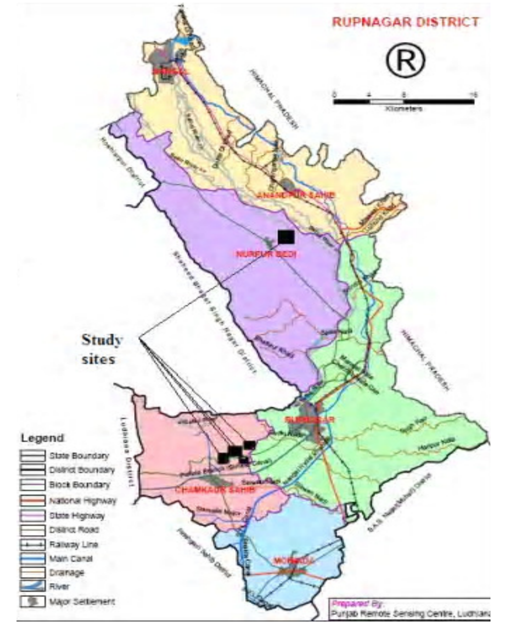

Fig. A : Location map of different experimental sites

Table A : Important soil physico-chemical properties of surface (0-15 cm) soil samples of different experimental sites

Site (s)	pH (1:2), w/v*	E.C. (1:2), w/v	OC ($g\ kg^{-1}$)	Av-P ($kg\ ha^{-1}$)	Av-K ($kg\ ha^{-1}$)	Av-S ($kg\ ha^{-1}$)	Soil texture
Rasidpur (S_1)	7.47	0.258	4.45	30.2	112.5	26.7	Sandy loam
Rasidpur (S_2)	7.94	0.239	4.55	22.5	181.3	31.9	Sandy loam
Asalatpur (S_3)	8.01	0.324	3.25	34.6	132.0	34.4	Sandy loam
Asalatpur (S_4)	8.04	0.234	4.05	34.3	172.5	24.2	Loamy sand
Wajidpur (S_5)	7.27	0.358	4.45	32.5	162.5	27.6	Sandy loam

*Weight/volume basis

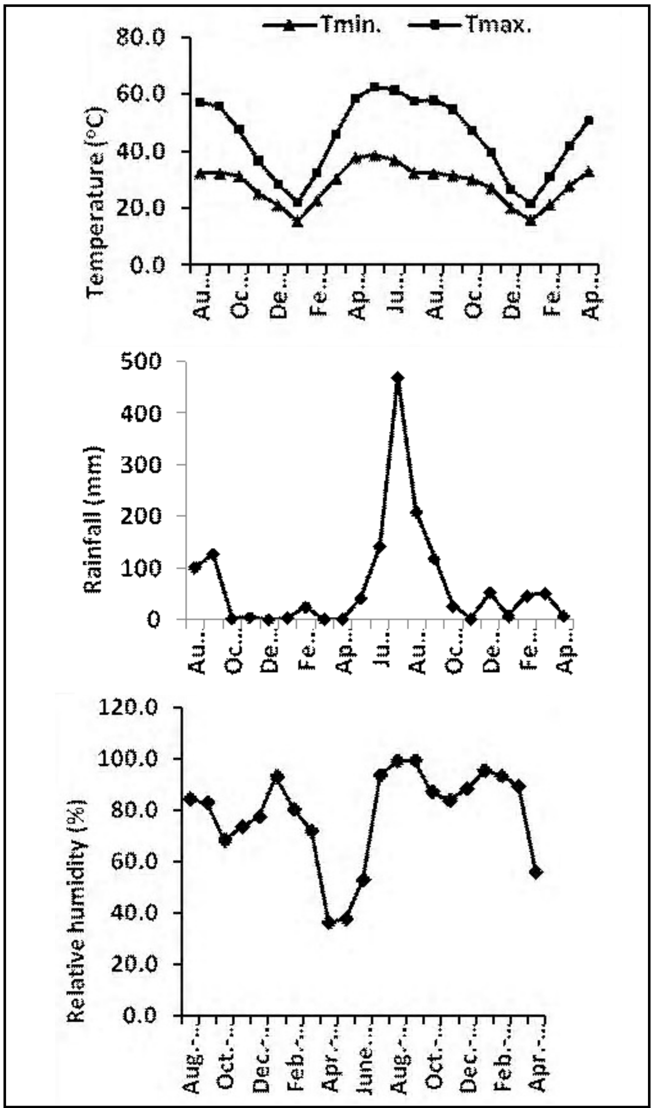

Fig. B : Fluctuation in mean maximum ($T_{max.}$) and minimum ($T_{min.}$) temperature (oC) rainfall (mm) and relative humidity (%)during the study period

After the harvesting of wheat (*Rabi* 2009-10) the soil samples were collected from fields where maize (*Zea mayz* L.)-wheat (*Triticum aestivum* L.) cropping sequence was in practice for more than last 5-years. The important physico-chemical characteristics of surface soil (0-15 cm) layer of five experimental locations, before the start of experiment are presented in Table A. The soil samples (*Acquic Ustorthents*, US Taxonomy) were analyzed for pH (1:2; soil: water), electrical conductivity (1:2; soil: water), soil organic carbon (Walkley and Black, 1934), Available-P (Olsen *et al.,* 1954), available-K (Pratt, 1982) and available S (Chesnin and Yein, 1951).

Treatments details:

The fertilizer treatments consisted of 100 per centNPK (T_1), 100 per cent NPK+S @ 30.0 kg S ha^{-1} (T_2), farmer's practice (FP) of applying fertilizer (T_3), FP+30.0 kg K_2O ha^{-1} (T_4), FP+30.0 kg S ha^{-1} (T_5), FP+30.0 kg K_2O ha^{-1}+ 30.0 kg S ha^{-1} (T_6) replicated at all locations. The fertilizer dose for maize receiving 100 per cent NPK rate consisted of 125-60-30 kg N-P_2O_5-K_2O ha^{-1}, through urea (46% N), di-ammonium phosphate (DAP, 46% P_2O_5 after adjusting N) and murate of potash (MOP, 60% K_2O). However, P and K in T_1 and T_2 were applied only in deficient soils (Olsen-P<12.5 kg ha^{-1} and available-K <137.5 kg ha^{-1}, respectively). For S, gypsum (12% S) was applied. The fertilizer dose for other treatments was thus adjusted accordingly. The treatments at different locations were replicated in plots of varying size with 250-350 m^2 at each site and were arranged in a completely randomized block design (CRBD). Maize was seeded in the last week of May with pre-sowing irrigation in rows 60 cm apart with plant-to-plant distance of 22 cm. Full dose of P, K, S and 1/3rd N was applied at sowing time and second and third N dose was applied at knee height and pre-flowering stages, respectively. The crop was harvested in the month of September and crop biomass in addition to agronomic characters that attribute towards yield from different treatments were recorded.

Statistical analysis:

The statistical analysis of crop yield and yield attributes *viz.,* plant height, cob length and test (1000-grain) weight was carried out by analysis of variance in completely randomized block design, CRBD (Cochran and Cox, 1950) using CPCS-1 software (CPCS-1, 1990). The mean separation for different treatments was performed using the least significant difference (LSD) test at 0.05 level of probability. The production efficiency of crop as influenced by fertilizer application was worked out as described by Tomar and Tiwari (1990). The economic efficiency of fertilizer application was calculated from the average net-returns on unit area basis and average crop duration. The energy input and output was calculated using energy equivalent as suggested by Devasenapathy *et al.* (2009) considering input energy associate with nutrient and FYM application only. Energy use efficiency was worked out from the ratio of total output and total input energy (Nedunchezhiyan, 2010). The energy productivity related to fertilizer application through NPK and FYM was calculated after dividing total production by total energy used (Devasenapathy *et al.,* 2009).

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Crop yield and yield attributes:

The effect of different balanced fertilization application strategies in maize was assessed through various crop yield

Table 1 : Effect of potassium and sulphur application on yield attributes and efficiency of maize

Treatments	Plant height (cm)*	Cob length (cm)*	Cobs plant^{-1*}	1000-grain weight (g)*	Maize yield (q ha^{-1})*	Increase in yield (%) over FP (T_3)
T_1	223^d	21.9^b	1.0^a	257^d	49.8^d	19.1
T_2	228^e	22.7^c	1.0^a	261^e	53.5^e	28.0
T_3	218^a	20.8^a	1.0^a	248^a	41.8^a	--
T_4	220^b	21.0^a	0.8^a	251^a	44.8^b	7.2
T_5	219^b	21.3^a	0.8^a	253^b	46.6^c	11.5
T_6	221^c	21.3^a	1.0^a	256^c	47.8^c	14.4

*Different letters in each column for at particular study site differs significantly ($p \leq 0.05$)

attributes *viz.,* plant height, cob length, number of cobs plant^{-1} and test weight (1000-grain weight). The average maize plant height was 218 cm in FP (T_3) plots in comparison to 223 cm (T_1) plots receiving 100 per cent NPK (Table 1). However, the significantly higher average maize plant height was observed in T_2 plots receiving S conjointly with 100 per cent NPK over either compared treatment. On the other hand, the average plant height in T_4 and T_5 plots differed non-significantly. Present result corroborates the findings of Sharma (1983), who reported significant increase in plant height and number of leaves per plant of maize with the balanced fertilizer (NPK) application. Significant increase in maize plant height with the application of 100 per cent NPK over FP has also been reported by Achieng *et al.* (2010). Earlier, Alam and Islam (2003) also reported significant increase in 1000-grain weight of maize with the application of 20.0 kg S ha^{-1} over no-S control. The soil K application has been reported to increase fertilization by adjusting period between tasseling and silking and thereby resulting in more number of grain rows, grain cob^{-1} and produced higher grain weight cob^{-1} (Haji *et al.*, 2011).

The average cob length in T_1 plots (21.9 cm) was significantly higher than cob length of maize harvested from either of compared treatments except T_2, emphasizing the influence of S application conjointly with 100 per cent NPK (Table 1). On the contrary, however, the number of cobs per plants differed non-significantly for all the compared treatments. The test weight of maize also exhibited a lowest in FP (T_3) plots and highest in T_2 plots. The results revealed that the test weight of maize exhibited a significant increase of 4.0 and 5.2 per cent, respectively with the application of 100 per cent NPK and 100 per cent NPK+S, over FP (T_3). According to Stefano *et al.* (2004), the application of balanced inorganic fertilizers exerts synergistic influence on plant growth, development and yield owing to improved cell activities, enhanced cell multiplication, enlargement and luxuriant growth (Fashina *et al.*, 2002) and better utilization of solar radiation (Saeed *et al.*, 2001). In sandy clay loam soils, Bharathi and Poongothai (2008) also reported significant increase of 12.4 per cent in maize grain yield with the application of 30.0 kg S ha^{-1} over no-S control.

The average maize grain yield was 41.8 q ha^{-1} in FP (T_3) plots and increased significantly to 44.8 q ha^{-1} in T_4 receiving 30.0 kg K_2O ha^{-1} in addition to T_3 (Table 1). Similarly, the average maize grain yield increased significantly by 11.5 per cent with the application of 30.0 kg S ha^{-1} in addition to FP (T_3). The conjoint application of 30.0 kg K_2O ha^{-1} and 30.0 kg S ha^{-1} in addition to FP, further exhibited a significant increase in maize grain yield over FP alone (T_3). Likewise, the plots receiving 100 per cent NPK (T_1) yielded 19.1 per cent higher maize yield than T_3. However the yield difference was 28.0 per cent when T_3 was compared with T_2, demarcating the synergistic effect of S application to maize. It was interesting to observe that the maize yield in FP plots (T_6) receiving S and K application coupled with >60 per cent higher NP application rate was 11.9 per cent lower than T_2 plots (Table 1). It was further observed that farmer's skipped N application at sowing that has made the difference in yield albeit of higher dose of N application in FP plots than 100 per cent NPK plots. Earlier, Achieng *et al.*

Table 2 : Effect of potassium and sulphur application on yield and economic parameters of maize

Treatments	Average cost of cultivation	Average gross returns*	Average net returns	BC ratio	Economic efficiency
		(` ha^{-1})			(` day^{-1} ha^{-1})
T_1	14,563	39,732	25,169	1.73	262.2
T_2	14,783	42,672	27,889	1.89	290.5
T_3	15,613	33,348	17,735	1.14	184.7
T_4	15,888	35,700	19,812	1.25	206.4
T_5	18,533	36,708	18,175	0.98	189.3
T_6	16,108	38,136	22,028	1.37	229.5

*Different letters in each column for at particular study site differs significantly ($p \leq 0.05$)

** Gross returns were worked out by considering MSP for maize (` 840/- q^{-1})

Table 3 : Total energy input and output, energy use efficiency and energy productivity of maize as influenced by fertilizer application

Treatments	Total input energy	Total output energy	Energy use efficiency	Energy productivity
	(X 10^3 MJ ha^{-1})			(kg MJ^{-1})
T_1	8.264	124.5	15.1	0.603
T_2	8.564	133.8	15.6	0.625
T_3	13.459	104.5	7.76	0.311
T_4	13.593	112.0	8.24	0.330
T_5	13.759	116.8	8.49	0.339
T_6	13.893	119.5	8.60	0.344

(2010) also reported significant augmentation (2.32-fold) in maize grain yield with the application of 100 per cent NPK over FP (only NP application) at Kenya.

Economics of crop production with fertilizer application:

The economic analysis of maize production with different fertilizer application strategies was assessed through average gross and net-returns and benefit-cost (BC) ratio. The varying average cost of cultivation from ‘14,563/- ha^{-1} to ‘18,533/- ha^{-1} for different compared treatments (Table 2) relates to the varying dose of NPK fertilizer applied in different treatments. The average gross returns of maize production in different fertilizer treatments plots was worked out by considering minimum support price (MSP) for maize (‘840/- q^{-1}). The average gross returns were highest in T_2 plots and lowest in FP plots (T_3) that are related with the crop yield for a particular treatment (Table 2). The comparison of T_1 and T_2 revealed that, average gross returns from maize were higher by ‘2,940/- ha^{-1} for T_2 over T_1, emphasizing the influence of S application. The average net-returns of maize production with fertilizer application also followed the similar trend to that of average gross returns (Table 2). The highest average net-returns in T_2 plots commensurate with the highest maize grain yield coupled with lowest cost of cultivation for the treatment. The economic credibility of balanced fertilizer use in T_2 plots over either of the compared treatment was also reflected through highest BC ratio (1.89), showing highest returns to the farmer's.

Production and economic efficiency of maize with fertilizer application:

The efficiency of fertilizer application to maize was also assessed through production and economic efficiency. The production efficiency of maize that depicts quantity of grain produced per day on unit area basis has been shown in Fig. 1. The production efficiency of maize was 39.7 kg grains d^{-1} ha^{-1} in FP plots (T_3) and increased by 6.3 per cent (42.5 kg grains d^{-1} ha^{-1}) in T_4 plots receiving 30.0 kg K_2O ha^{-1} in addition to FP (T_3). However, the production efficiency exhibited an increase of 10.1 per cent with the application of 30.0 kg S ha^{-1} over T_3 (Fig. 1). On the other hand, the conjoint application of 30.0 kg K_2O ha^{-1} and 30.0 kg S ha^{-1} along with T_3 has further registered an increase in the production efficiency of maize by 14.4 per cent over T_3. Over and above, the production efficiency of maize was 19.1 and 28.0 per cent higher for T_1 and T_2 treatments over T_3 plots, further demarcating the importance of balanced fertilization in maize. The highest economic efficiency (‘290.5 d^{-1} ha^{-1}) for T_2 plots as compared to either of the compared treatment again recapitulates the higher monetary returns to the farmer's with balanced fertilization to maize in the studied floodplain soils.

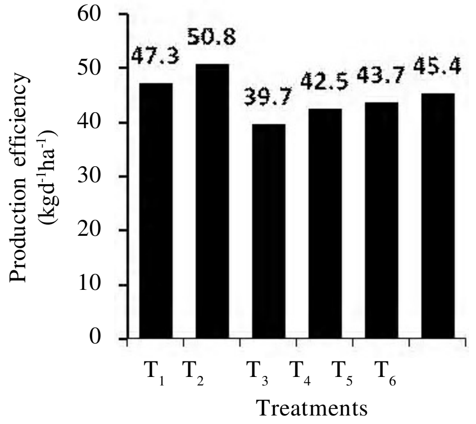

Fig. 1 : Effect of different treatments on production efficiency on maize

Energy relationship of maize with fertilizer application:

The energy relationships for the maize were worked out by considering input energy associated with the application of fertilizer in different plots (Table 3). The total input energy in T_3 plots was 13.459 x 10^3 MJ ha^{-1} that was 63.1 per cent higher than total input energy involved for maize production in T_1 receiving 100 per cent NPK. However, for T_2 receiving S in addition to NPK was 8.564 x 10^3 MJ ha^{-1}, which resulted in production of highest total output energy. The comparison revealed 28.0 per cent higher total output energy in T_2 over FP (T_3) plots. The energy relationships associated with fertilizer application revealed total output energy of 133.8 x 10^3 MJ ha^{-1} in T_2 plots as compared to 104.5 x 10^3 MJ ha^{-1} in FP (T_3) plots, with 4.9 x 10^3 MJ ha^{-1} higher use of total input energy in FP plots than T_2 plots. Likewise, the lowest energy use efficiency was recorded in T_3 plots and highest in T_2 plots, demarcating the importance of balanced fertilizer use in maize. The energy productivity also showed a similar trend to that of total output energy with fertilizer application. The energy productivity of 0.625 kg MJ^{-1} was recorded for maize grown with balanced fertilizer use (T_2) in comparison to 0.311 kg MJ^{-1} for maize in FP (T_3) plots, receiving >60 per cent higher NP application. The highest energy productivity for maize in T_2 plots relates to the highest yield recorded from T_2 plots with the balanced fertilizer application (100% NPK+S).

Conclusion:

The results of present investigation revealed a significant increase in average maize plant height, cob length, test weight (1000-grain weight) and maize grain yield with the application of balanced use of fertilizers (100% NPK+S). The balanced fertilizer use in maize resulted in higher production and economic efficiency, total output energy, energy productivity and energy use efficiency. The economics of fertilizer application assessed through average gross and net-returns and BC ratio, further demarcates the importance of balanced fertilizer application in maize grown in floodplain soils.

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