Combined Effect of Zinc and Boron with Macronutrients on Growth and Performance in Maize- Blackgram Cropping System

[1]M. Naveen Saviour, [2]P. Stalin, [3]S. Mani, [4]P. Muthukrishnan and [5]K. Valliappan

[1]Ph. D Scholar, [2,3]Professor, Department of Soil Science and Agricultural Chemistry,

[4,5]Professor, Department of Agronomy, [5]Dept. of Environmental Sciences

Tamil Nadu Agricultural University, Coimbatore- 641 003

mnaveenssac@gmail.com, agri_naveen@rediffmail.com Mobile: 9842526193

Abstract

In India, increasing deficiency of secondary and micronutrients has been started decreasing the crop response to NPK application. Adding more NPK fertilizer does not produce a proportionate increase in crop production and nutrient use efficiency is reduced affecting the productivity and sustainability. Hence, adoption of balanced fertilization involving major, secondary and micronutrient is needed for the efficient use of nutrients in the current production scenario. Keeping this in view, field experiments were conducted during 2011-12 in maize- blackgram cropping system to determine the effect of boron (B) and zinc (Zn) on yield and yield components in B and Zn-deficient black and red soils (Fine loamy hyperthermic Ultic Haplustalfs) in Pudukkottai district, Tamil Nadu. The treatments included for the main crop maize hybrid (NK-6240) and residual blackgram (var.Vamban-3) were three levels of NPK as main plot treatments M_1: Control (No NPK), M_2: 75% NPK kg ha^{-1}, M_3: 100% NPK ha^{-1} (250:75:75) and nine levels of sub plot treatments as $ZnSO_4$ @ 37.5 kg ha^{-1} (S2), 50 kg $ZnSO_4$ ha^{-1}(S3), 10 kg Borax ha^{-1}(S4), 15 kg Borax ha^{-1} (S5), 37.5 kg $ZnSO_4$ ha^{-1} + 10 kg Borax ha^{-1} (S6), 37.5 kg $ZnSO_4$ ha^{-1} + 15 kg Borax ha^{-1} (S7), 50 kg $ZnSO_4$ ha^{-1} + 10 kg Borax ha^{-1} (S8) and 50 kg $ZnSO_4$ ha^{-1} + 15 kg Borax ha^{-1} (S9) and also without application of fertilizers was maintained as absolute control (S1) in split plot design. Results revealed that application of $ZnSO_4$ and Borax @ 37.5 kg and 10 kg ha^{-1} respectively combined with recommended 100% NPK ha^{-1} significantly recorded the highest dry grain (7.1 t ha^{-1}) and straw yield (14.1 t ha^{-1}). The grain yield increase were 65.5 per cent and the straw yield increase was 63.1 over control respectively. For residual crop black gram, application of $ZnSO_4$ and Borax @ 50 kg and 10 kg ha^{-1} respectively combined with recommended 100% NPK ha^{-1} significantly recorded the highest grain (690 kg ha^{-1}) and haulm yield (803 kg ha^{-1}). However, this treatment was on par with application of $ZnSO_4$ and Borax @ 37.5 kg and 10 kg ha^{-1}. Hence, in Zn and B deficient soil, combined application of $ZnSO_4$ and Borax @ 37.5 kg and 10 kg ha^{-1} along with 100% NPK ha^{-1} may be recommended for enhancement of yield in maize- blackgram cropping system.

(Key words: maize- blackgram, zinc, boron, grain, stover, pod and haulm yield)

Introduction

In India, increasing deficiency of secondary and micronutrients has been started decreasing the crop response to NPK application. Adding more NPK fertilizer does not produce a proportionate increase in crop production and nutrient use efficiency is reduced affecting the productivity and sustainability. Micronutrient deficiencies in crop plants are widespread because of (i) increased micronutrient demands from intensive cropping practices and adaptation of high-yielding cultivars which may have higher micronutrient demand, (ii) enhanced production of crops on marginal soils that contain low levels of essential micronutrients, (iii) increased use of high-analysis fertilizers with low amounts of micronutrients, (iv) decreased use of animal manures, composts, and crop residues, (v) use of many soils that are inherently low in micronutrient reserves, (vi) use of liming in acid soils, and (vi) involvement of natural and anthropogenic factors that limit adequate supplies and create elemental imbalance (Fageria et al., 2002). Among micronutrients, boron (B) and zinc (Zn) play a key role in pollination and seed set processes, so that their deficiency can cause decrease in seed formation and subsequent yield reduction.

Maize, one of the important food crops in most world's area, is sensitive to Zn deficiency. Stunded and chlorotic plants due to Zn deficiency are often observed on early grown plants in the plants (Liu et al., 1996). Maize is a Zn-intensive plant with a high Zn- demand that very positively responds to Zn dressing under low levels of available Zn in the soil (Kovacevic *et al*., 2004). Boron is an essential element for plant growth and yield. Among the cereals, maize is relatively more susceptible to B deficiency (Agarwala and Sharma, 1979). Boron also plays an important role in increasing the grain fruiting in maize as stated by Yiying Li and Hong Lang (1997). Rehem et al (1998) stated that B plays a key role in water and nutrients transportation from root to shoot. Vitosh et al., (1997) expressed that B is involved in carbohydrates metabolism and it is essentially necessary for protein synthesis, pollen germination and seed and cell wall formation. In India, maize occupies 7.42 million hectares with a production and productivity of 14.2 million tones and 1983 kg ha^{-1} respectively (Singh et al., 2007). Maize is grown in Tamil Nadu in about 2.44 lakh ha with a total production of 11.38 lakh tonnes and a productivity of 4461 kg ha^{-1} (Season and Crop Report, 2009-10). Blackgram is a promising pulse crop and it is preferred much for its nutritional quality of high protein. India has the largest area of 2 million hectares under blackgram cultivation in the world. However the yield of 567 kg ha^{-1} is lower among the countries in the world. In Tamil Nadu, Blackgram is being grown in an area of 2.59 lakh hectares with a total production of 0.98 lakh tonnes and a productivity of 380 kg ha^{-1} (Season and Crop Report, 2009-10). Among micronutrients, zinc deficiency in agricultural crops is a common disorder in a wide variety of soils and about 49% as well as 58% of the soils used for cultivation in India and in Tamil Nadu respectively are Zn-deficient, which reduce not only the yield but also nutritional quality of the produce. Zinc deficiency in Indian soils is expected to increase from 42 % in 1970 to 63% by 2025 due to continuous depletion of soil fertility. It has been estimated, the overall per cent deficiency of micronutrients in Tamil Nadu soils viz., Zn, Fe, Mn and Cu were 58, 17, 6 and 6 per cent respectively (Velu *et al.* 2008).

At present for alleviating Zn and boron deficiency, besides some customized products, zinc sulphate and borax are the common fertilizers available to the farmers in the market**.** Moreover the yield of these crops are comparatively low in Tamil Nadu because of our farmers' inadequate knowledge about the beneficial role of micronutrients especially zinc and boron in increasing the production of crops. Since NPK fertilizer does not produce a proportionate increase in crop production and sustainability, adoption of balanced fertilization involving major, secondary and micronutrient is needed for the efficient use of nutrients in the current production scenario. In this background, field experiments having various levels of zinc sulphate and borax were carried out to study the concentration and the removal by zinc and boron in maize and blackgram cropping system.

Materials and methods

The experiments were conducted during 2011-12 in maize- blackgram cropping system in farmers holdings of B and Zn-deficient red and black soils (Fine loamy hyperthermic Ultic Haplustalfs) in Pudukkottai district, Tamil Nadu.

Treatment details:

The treatments included for the main crop maize hybrid (NK-6240) and residual blackgram (var.Vamban-3) were three levels of NPK as main plot treatments M_1: Control (No N, P and K), M_2: 75% NPK kg ha^{-1}, M_3: 100% NPK ha^{-1} (250:75:75) and nine levels of sub plot treatments as $ZnSO_4$ @ 37.5 kg ha^{-1} (S2), 50 kg $ZnSO_4$ ha^{-1}(S3), 10 kg Borax ha^{-1} (S4), 15 kg Borax ha^{-1} (S5), 37.5 kg $ZnSO_4$ ha^{-1} + 10 kg Borax ha^{-1} (S6), 37.5 kg $ZnSO_4$ ha^{-1} + 15 kg Borax ha^{-1} (S7), 50 kg $ZnSO_4$ ha^{-1} + 10 kg Borax ha^{-1} (S8) and 50 kg $ZnSO_4$ ha^{-1} + 15 kg Borax ha^{-1} (S9) and also without application of fertilizers was maintained as absolute control (S1) in split plot design.

Field experiment details

Field experiment of maize- blackgram cropping system consisted of 27 treatments replicated thrice imposed with fertilizer Sources viz; Urea (46% N), Super (16% P), Potash (60% K), Zinc Sulphate (Zn -21%), Borax (B- 11%) and Gypsum (18% S). The fertilizer requirement for the Maize hybrid NK 6240 followed was 250:75:75 NPK kg ha^{-1}. Uniform dose of 40 Kg S ha^{-1} in the form of gypsum for maize and 20 Kg ha^{-1} for blackgram will be applied to all treatment plots. The recommended dose of 250:75 kg N and P_2O_5 ha^{-1} were applied through urea and super phosphate to the all treatments (¼ of N and full of P_2O_5 as basal and remaining N was applied in two equal split doses during vegetative and tasselling stages of maize). The recommended (100 %) dose of 75 kg K_2O ha^{-1} was applied basally through muriate of potash and before sowing of seeds, the required quantity of Zn and B were also applied through $ZnSO_4$ and Borax. The field experiment initial soil analysed were listed below in (table. 1). Need based plant production and protection measures were taken up and the crops were grown to maturity and harvested. The biometric observations, grain and straw yield were recorded during harvest stage of crop. ANOVA was performed using the standard procedures to compare the effect of various treatments.

Results and Discussion

Maize crop- Dry matter Production

The dry matter production of maize crop was significantly influenced by different treatment combinations over control in all the critical stages. During the harvest stage, the highest value (table 2) was associated (8.97 t ha^{-1}) with application of 37.5 kg $ZnSO_4$ ha^{-1} + 10 kg Borax ha^{-1} along with 100% recommended NPK (M_3S_6) and the lowest (1.92 t ha^{-1}) was recorded in control (M_1S_1) than the treatments enhanced with NPK or Zn and B or combined with NPK or Zn and B. The favourable influence of B on dry matter production may be due to the enhanced availability of B in the soil that plays a significant role in growth attributes which in turn influences dry matter production. The increase in dry matter production with the addition of B was also observed by Bhilegaonkar *et al*., (1995).

Yield attributes

The results for the yield attributes (table.3) indicated that the beneficial effect of the micronutrients (Zn and B) in influencing the number of grains cob^{-1} and 100 grain weight (g) was noticed in this experiment. Application of 37.5 kg ZnSO4 ha^{1}+10 kg Borax ha^{-1} along with 100% recommended NPK (M_3S_6) to the soil showed a profound effect in increasing the yield parameters. The same treatment registered significantly the highest number of grains cob^{-1} and (567) and 100 grain weight (41.7 g). As boron is reported to be involved in reproductive process and development of more grain (Nyomora *et al.*, 1997) there are ample chances for the development of more grains on a cob occupying the entire length with grains. Increase in 100 seed weight due to boron application might enhanced the uptake and translocation of sugar and is also implicated in carbohydrate metabolism (Mitra and Jana, 1991). The lowest number of grains cob^{-1} and 100 grain weight (g) was registered in the absolute control with 312 and 20.4g respectively than the treatments enhanced with NPK or Zn and B or combined with NPK or Zn and B. According to Brown et al., (1993) formation of male and female reproductive organs and pollination process are disturbed in Zn deficiency, which in result causes a sever reduction in plant yield.

Grain and straw yield

The yield data revealed that significant differences were noticed among different treatment combinations over control. In the main crop maize, The grain and stover yields ranged from 2.45 to 7.10 t ha^{-1} and 5.20 to 14.10 t ha^{-1} respectively. Application of 37.5 kg ZnSO4 ha^{-1} +10 kg Borax ha^{-1} along with 100% recommended NPK (M_3S_6) registered significantly the highest yield of grain (7.1 t ha^{-1}) and stover (14.1 t ha^{-1}). The grain and straw yield increase being 65.5 and 63.1% over control (table 4). This yield increase was mainly due to significant improvement in the yield attributes due to balanced supply of nutrients. Further, this finding is in agreement with Parthiban and Prem Sekhar (2003) and by other workers (Paramasivam *et al.* 2010; Singh and Vyas, 1998; Ziaeyan and Rajaie, 2009). Similar findings were also reported by Singh and Sarkar (2001) and Balyan *et al.* (2006). The application of 37.5 kg ZnSO4 ha^{-1}+15 kg Borax ha^{-1} along with 100% recommended NPK (M_3S_7) resulted in the next highest grain and stover yields (6.8 t ha^{-1} and 12.40 t ha^{-1}). The lowest grain and stover yield was registered in the absolute control (2.45 t ha^{-1} and 5.20 t ha^{-1}) than the treatments enhanced with NPK or Zn and B or combined with NPK or Zn and B. The use of micronutrients increased the yield when applied in combination of macronutrients as compared to conventional fertilization which lack micronutrients (Bakry *et al.,* 2009; Singh *et al.,* 2009; Azhar Ghaffari, 2011). On-farm studies conducted during three seasons (2002–2004) demonstrated significant yield responses of maize, castor. Groundnut and mungbean to the applications of S, B and Zn; the yield responses were larger when S, B, and Zn were applied along with N and P (Rego et al., 2007). It was concluded that balanced nutrition of crops was essential for sustained increases in yields of field crops.

Residual blackgram- Yield attributes

The data revealed that the effect of the micronutrients (Zn and B) greatly influenced the yield attributes viz., the number of grains cob^{-1} and 100 grain weight (g) of residual black gram. Application of 50 kg $ZnSO_4$ ha^{-1}+10 kg Borax ha^{-1} along with 100% recommended NPK (M_3S_8) evidenced marked effect in increasing the yield parameters (Table5). The same treatment registered significantly the highest number of pods $plant^{-1}$ (25.8) and 100 seed weight (4.4 g) which is statistically on par with the treatment combination M_3S_6. The lowest number of pods $plant^{-1}$ (9.1) and 100 seed weight (2.1 g) was registered in the absolute control.

Pod and haulm yield

The results of the experiments revealed that significant differences were found within the different treatment combinations over control. For residual crop blackgram, the pod and haulm yield (table 6) ranged from 330 to 690 kg ha^{-1} and 395 to 803 kg ha^{-1} respectively. The significant increase in dry pod (690 kg ha^{-1}) and haulm yield (803 Kg ha^{-1}) was recorded with the application of 50 kg ZnSO4 ha^{-1} + 10 kg Borax ha^{-1} along with 100% recommended NPK (M_3S_8) which is statistically on par with the treatment combination M_3S_6. Application of 37.5 kg ZnSO4 ha^{-1}+10 kg Borax ha^{-1} along with 100% recommended NPK (M_3S_6) resulted in the next highest yield of pod (681 kg ha^{-1}) and haulm (798 $kgha^{-1}$). The pod and haulm yield increase being 52.1 and 50.8 % over control (table 5&6). Islam *et al.* (1997) reported a yield increase of 41.8 per cent due to the application of Zn + B + S in rice - mustard cropping system. The lowest pod and haulm yield was registered in the absolute control (330 kg ha^{-1} and 395 kg ha^{-1}) than the treatments enhanced with NPK or Zn and B or combined with NPK or Zn and B.

Conclusion:

Zinc and boron nutrition has immense importance in enhancing the productivity of crops. In maize- blackgram cropping system, application of $ZnSO_4$ and Borax @ 37.5kg and 10 kg ha^{-1} along with 100% recommended NPK increased the yield considerably in zinc and boron deficient soils. It is essential that the availability of micronutrients status of cultivable soils has to be analysed on regular basis to ensure optimum yields.

References

[1]. Agarwala, S. C. and Sharma, C. P. 1979. Recognizing Micronutrient Disorders of crop plants on the basis of visual symptoms and plant analysis. Department of Botany, Lucknow University, Lucknow.

[2]. Azhar Ghaffari. 2011. Influence of Integrated Nutrients on Growth, Yield and Quality of Maize (*Zea mays* L.). *Am. J. Plant Sci.,* **2:** 63-69.

[3]. Balyan. J. K., Singh, P., Kumpawat, B. S and Jain, L. K. 2006. Effect of integrated nutrient management on maize (*Zea mays* L.) growth and its nutrient uptake. *Curr. agric.,* **30**: (1-2): 79-82.

[4]. Bakry, M. A., Y. R. Soliman and S.A. Moussa. 2009. Importance of micronutrients, organic manure and bio-fertilizer for improving maize yield and its components grown in desert sandy soils. *Res. J. Agric. and Biol. Sci*., **5:** 16-23.

[5]. Bhilegaonkar, M.W., Ekshinge, B.S. and Karle , B.G. 1995. Effects of phosphorus, sulphur and boron levels on dry matter and grain yield of safflower.

J. Maharastra Agric.Univ.,**20** (1):132-136.

[6]. Brown, P.h., Cakmak, I. Zhang, Q. 1993. Forms and function of zinc in plants. Zinc in soils and plants. In: A.D. Robson (ed). pp. 93-1.6. Kluwar Academic Publishers, Dordecht, The Netherlands.

[7]. Fageria, N. K., Baligar, V. C. and Clark, R. B. (2002. Micronutrients in crop production. *Adv. Agron.* 77 : 185-268.

[8]. Islam, MR., Raisat, T.M and Jahiruddin, M. 1997. Direct and residual effect of S, Zn and B on yield and nutrient uptake in a rice - mustard cropping system. *J. Indian Soc. Soil Sci.,* **45** (1): 126- 129.

[9]. Kovacevic, V., I. Brkic, D. Simic, G. Bukvic and M. Rastija. 2004. The Role of Genotypes on Phosphorus, Zinc, Manganese and Iron Status and Their Relations in Leaves of Maize on Hydromorphic Soil. *Plant Soil Environment,* **50** (12): 535-539.

[10]. Liu, Z., 1996. Microelements in Soils of China. Jiangsu Science and Technology Publishing House, Nanjing, pp: 177-203.

[11]. Mitra, A.K and Jana, P.K. 1991. Effect of doses and method of boron application on wheat in acid Terai soils of North Bengal. *Indian Journal of Agronomy.,* **36** (1):72-74.

[12]. Nyomora, A.M.S., Bravn, P.H and Freeman, M. 1997. Foliar applied boron increases tissue boron concentration and nut set of almond. *Journal of American Soceity of Horticulture Science.,* (In Press).

[13]. Paramasivam, M., K.R. Kumaresan, P. Malavizhi, S. Mahimairaja and K.Velayudham. 2010. Effect of different levels of NPK and Zn on yield and uptake of hybrid maize (C0HM 5) (*Zea mays* L.) in Madukkur (MDK) series of soils of Tamil Nadu. Asian *J. Soil Sci.,* **5** (2): 236-240.

[14]. Parthiban, T and Sekhar, Prem M. 2003. Response of hybrid maize to different levels and time of N fertilization under irrigated condition. *J. agri. Resource Management,* **2** (1&2): 41-46.

[15]. Rego, T. J., K. L. Sahrawat, S. P. Wani, and G. Pardhasaradhi. 2007.Wide spread deficiencies of sulfur, boron, and zinc in Indian semarid tropical soils: On-farm crop responses. J*ournal of Plant Nutrition.* **30**: 1569- 1583.

[16]. Rehem, G. W., Fendter, W. E., and Overdahi, C. J. 1998. Boron for Minnesota soils. University of Minnesota. Extension Service [Online]. Available at http://www. Extansion Umn. Edv

[17]. Season and Crop Report of Tamil Nadu, 2009-10. Department of Economics and Statistics, Chennai-6.

[18]. Singh, A and K. Vyas. 1998. Effect of N levels and zinc application on dry matter production and N, P and Zn content in maize. Haryana. *J. Agron*., **44** (2): 242-245.

[19]. Singh. Surendra and Sarkar, A. K. 2006. Balanced use of major nutrients for sustain higher productivity of maize (Zea mays L.) - wheat cropping system in acidic soils of Jharkhand. Indian *J. Agron*., **46**: 605-610.

[20]. Singh, N., Nanjappa, H. V. and Ramachandrappa, B. K. 2007. Influence of nutrient levels and critical period of crop weed competition on growth, yield and weed control in sweet corn (*Zea mays* L.cv saccharata). *Mysore J. Agric. Sci*., **41:** 191-198.

[21]. Singh, R. N., N. N. Nath, S. K. Singh, T. K. Mohan and J. P. Shahh. 2009. Effect of agronomic management practices on growth, yield and quality of kharif maize (*Zea mays* L.) under excessive moisture conditions**.** *Crop Res.,* **32** (3)**:** 302-305.

[22]. Vitosh, M. L., Warneke D. D and Lucas R. E. 1997. Boron. Mishigan State University Extention Soil and Manegement Fertilizer. Available on the htpp://www.Msue.msu.EDV.

[23]. Velu, V., Usha Mathew and Bhaskar, A. (2008). Scenario of Micro and Secondary nutrient deficiencies in the states of Tamil Nadu, Kerela and Pondicherry and amelioration practices for increasing crop production and ensuing food security. Proc. of National seminar on ‘Micro and Secondary Nutrients for Balanced Fertilization and Food Security” held at Anand Agricultural University, Anand, 11- 12th March. pp 29-30.

[24]. Yiying Li and Hong Lang. (1997). Soil boron content and the effects of boron application on yields of maize, soybean, rice and sugarbeet in Heilogjiang Province, P.R. China, In : Boron in Soils and Plants. Ed. R.W. Bell and B. Rerkasem. Kulwer Academic Publishers. Netherlands. 17- 21.

[25]. Ziaeyan, A.H. and M. Rajaie. 2009. Combined effect of zinc and boron on yield and nutrients accumulation in corn. Int. *J. Plant Prod*., **3**: 33-45.

.

Table 1. Physico chemical characteristics of experimental soil

S. No	Soil test parameters	Test Values	Test rating
1	Soil texture	Clay- 16.3 %, Silt 21.0 % Fine sand- 23.2 %, Coarse- 39.2 %	Sandy loam
2	Soil pH	6.42	Near neutral
3	Electrical Conductivity (dSm^{-1})	0.07	Low
4	Organic carbon (%)	0.33	Low
5	Available nitrogen ($kg\ ha^{-1}$)	264	Low
6	Available phosphorus ($kg\ ha^{-1}$)	15.4	Medium
7	Available potassium ($kg\ ha^{-1}$)	222	Medium
8	DTPA- Fe ($mg\ kg^{-1}$)	14.2	Sufficient
9	DTPA- Mn ($mg\ kg^{-1}$)	8.30	Sufficient
10	DTPA- Zn ($mg\ kg^{-1}$)	0.84	Deficient
11	DTPA- Cu ($mg\ kg^{-1}$)	1.37	Sufficient
12	HWS boron ($mg\ kg^{-1}$)	0.20	Deficient

Table 2. Effect of micronutrients (Zn and B) on dry matter production (t ha^{-1}) of maize at different growth stages

NPK levels (kg ha^{-1})	Micronutrients levels (Zn and B) (kg ha^{-1})									
	S_1 (Zn_0B_0)	S_2 ($Zn_{37.5}$)	S_3 (Zn_{50})	S_4 (B_{10})	S_5 (B_{15})	S_6 ($Zn_{37.5}B_{10}$)	S_7 ($Zn_{37.5}B_{15}$)	S_8 ($Zn_{50}B_{10}$)	S_9 ($Zn_{50}B_{15}$)	Mean
	Vegetative Stage (t ha^{-1})									
M_1 (0)	0.37	0.54	0.67	0.49	0.55	0.68	0.59	0.56	0.58	0.6
M_2 (75%)	0.56	0.86	0.92	0.71	0.78	0.99	0.81	0.79	0.83	0.8
M_3 (100%)	0.77	1.23	1.28	0.98	1.13	1.44	1.19	1.15	1.18	1.2
Mean	0.6	0.9	1.0	0.7	0.8	1.0	0.9	0.8	0.9	0.8
	Tasselling Stage (t ha^{-1})									
M_1 (0)	0.45	0.91	0.94	0.58	0.79	0.99	0.71	0.75	0.81	0.8
M_2 (75%)	1.09	1.87	1.83	1.41	1.63	1.91	1.71	1.69	1.73	1.7
M_3 (100%)	1.32	2.56	2.61	1.98	2.13	3.14	3.01	2.98	2.92	2.5
Mean	1.0	1.8	1.8	1.3	1.5	2.0	1.8	1.8	1.8	1.6
	Cob initiation Stage (t ha^{-1})									
M_1 (0)	1.79	2.41	2.52	2.15	2.23	2.79	2.41	2.39	2.48	2.4
M_2 (75%)	2.99	4.82	4.54	4.22	4.65	5.23	4.83	4.84	4.89	4.6
M_3 (100%)	3.19	6.54	6.92	4.85	5.23	7.54	7.02	6.87	6.92	6.1
Mean	2.7	4.6	4.7	3.7	4.0	5.2	4.8	4.7	4.8	4.3
	Harvest Stage (t ha^{-1})									
M_1 (0)	1.92	2.67	2.98	2.46	2.57	3.30	2.94	2.78	2.82	2.7
M_2 (75%)	3.87	5.82	5.14	4.98	5.23	5.98	5.43	5.64	5.71	5.3
M_3 (100%)	4.45	7.45	8.34	5.10	6.23	8.97	8.01	7.45	7.78	7.1
Mean	3.4	5.3	5.5	4.2	4.7	6.1	5.5	5.3	5.4	5.0

	Vegetative				Tasselling				Cob initiation				Harvest			
	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.01	0.01	0.02	0.02	0.01	0.02	0.04	0.05	0.03	0.07	0.12	0.12	0.04	0.08	0.14	0.14
CD (0.05)	0.01	0.02	0.04	0.04	0.04	0.05	0.01	0.01	0.10	0.14	0.26	0.26	0.12	0.17	0.30	0.30

Table 3. Effect of micronutrients (Zn and B) on number of grains cob^{-1} and 100 grain weight (g) of maize

NPK levels (kg ha^{-1})	Micronutrients levels (Zn and B) (kg ha^{-1})									
	Number of grains cob^{-1}									
	S_1 (Zn_0B_0)	S_2 ($Zn_{37.5}$)	S_3 (Zn_{50})	S_4 (B_{10})	S_5 (B_{15})	S_6 ($Zn_{37.5}B_{10}$)	S_7 ($Zn_{37.5}B_{15}$)	S_8 ($Zn_{50}B_{10}$)	S_9 ($Zn_{50}B_{15}$)	Mean
M_1 (0)	312	327	342	358	371	387	373	366	368	356.0
M_2 (75%)	331	350	362	379	398	432	411	390	382	381.7
M_3 (100%)	352	368	410	422	451	567	449	432	441	432.4
Mean	331.7	348.3	371.3	386.3	406.7	462.0	411.0	396.0	397.0	390.0
	100 Grain weight (g)									
M_1 (0)	20.4	21.4	22.7	24.1	25.2	26.9	25.4	25.3	24.9	24.0
M_2 (75%)	22.1	23.4	25.2	27.2	28.3	32.2	29.1	30.2	29.5	27.5
M_3 (100%)	24.5	26.1	29.7	34.4	37.2	41.7	38.1	37.5	38.0	34.1
Mean	22.3	23.6	25.9	28.6	30.2	33.6	30.9	31.0	30.8	28.5

	Grains cob^{-1}				100 Grain weight (g)			
	M	S	M at S	S at M	M	S	M at S	S at M
SEd	2.54	6.14	10.35	10.64	0.21	0.45	0.77	0.88
CD (0.05)	7.06	12.35	21.29	21.39	0.58	0.91	1.58	1.58

Table 4. Effect of micronutrients (Zn and B) on grain and straw yield (t ha^{-1}) of maize

NPK levels (kg ha^{-1})	Micronutrients levels (Zn and B) (kg ha^{-1})									
	Grain yield (t ha^{-1})									
	S_1 (Zn_0B_0)	S_2 ($Zn_{37.5}$)	S_3 (Zn_{50})	S_4 (B_{10})	S_5 (B_{15})	S_6 ($Zn_{37.5}B_{10}$)	S_7 ($Zn_{37.5}B_{15}$)	S_8 ($Zn_{50}B_{10}$)	S_9 ($Zn_{50}B_{15}$)	Mean
M_1 (0)	2.45	2.45	3.20	3.45	3.65	3.90	3.85	3.75	3.75	3.38
M_2 (75%)	3.75	4.10	4.35	4.60	5.25	5.90	5.45	5.10	4.80	4.81
M_3 (100%)	4.25	4.30	4.50	5.20	6.00	7.10	6.80	6.35	6.00	5.61
Mean	3.48	3.62	4.02	4.42	4.97	5.63	5.37	5.07	4.85	4.60

Stover yield (t ha^{-1})										
M_1 (0)	5.20	6.10	7.30	7.90	8.20	9.95	9.10	8.80	8.75	7.92
M_2 (75%)	6.40	7.65	8.15	8.85	10.20	10.40	10.25	9.95	9.90	9.08
M_3 (100%)	8.10	8.95	10.4	10.90	12.15	14.10	12.40	12.20	10.45	11.07
Mean	**6.57**	**7.57**	**8.62**	**9.22**	**10.18**	**11.48**	**10.58**	**10.32**	**9.70**	**9.36**

	Grain yield				Stover yield			
	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.04	0.07	0.12	0.13	0.06	0.15	0.25	0.26
CD (0.05)	0.10	0.15	0.26	0.25	0.18	0.30	0.52	0.52

Table 5. Effect of micronutrients (Zn and B) on number of No. of pods plant $^{-1}$ and 100 seed weight (g) of residual black gram

NPK levels (kg ha^{-1})	Micronutrients levels (Zn and B) (kg ha^{-1})									
	No. of pods Plant^{-1}									
	S_1 (Zn_0B_0)	**S_2 ($Zn_{37.5}$)**	**S_3 (Zn_{50})**	**S_4 (B_{10})**	**S_5 (B_{15})**	**S_6 ($Zn_{37.5}B_{10}$)**	**S_7 ($Zn_{37.5}B_{15}$)**	**S_8 ($Zn_{50}B_{10}$)**	**S_9 ($Zn_{50}B_{15}$)**	**Mean**
M_1 (0)	9.1	9.9	11.2	13.1	14.9	16.4	15.1	16.8	15.4	13.5
M_2 (75%)	10.3	12.5	14.7	16.8	19.5	22.5	20.5	21.9	22.0	17.9
M_3 (100%)	13.8	15.6	18.4	22.5	24.2	25.6	23.8	25.8	23.1	21.4
Mean	11.1	12.7	14.8	17.5	19.5	21.5	19.8	21.5	20.2	17.6
100 seed weight (g)										
M_1 (0)	2.1	2.2	2.5	2.6	2.6	2.9	2.7	2.9	2.8	2.6
M_2 (75%)	2.3	2.4	2.6	2.8	2.8	3.2	2.8	3.3	2.9	2.8
M_3 (100%)	2.4	2.7	2.9	3.5	3.8	4.4	3.9	4.4	4.0	3.6
Mean	2.3	2.4	2.7	3.0	3.1	3.5	3.1	3.5	3.2	3.0

	No. of pods plant^{-1}				100 seed weight			
	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.14	0.28	0.48	0.49	0.02	0.05	0.08	0.08
CD (0.05)	0.37	0.57	0.99	0.99	0.05	0.10	0.18	0.18

Table 6. Effect of micronutrients (Zn and B) on pod and haulm yield (kg ha^{-1}) of residual black gram

NPK levels (kg ha^{-1})	Micronutrients levels (Zn and B) (kg ha^{-1})
	Pod yield (kg ha^{-1})

	S_1 (Zn_0B_0)	**S_2 ($Zn_{37.5}$)**	**S_3 (Zn_{50})**	**S_4 (B_{10})**	**S_5 (B_{15})**	**S_6 ($Zn_{37.5}B_{10}$)**	**S_7 ($Zn_{37.5}B_{15}$)**	**S_8 ($Zn_{50}B_{10}$)**	**S_9 ($Zn_{50}B_{15}$)**	**Mean**
M_1 (0)	330	345	368	383	405	415	375	417	370	380
M_2 (75%)	365	390	430	467	510	563	525	571	480	478
M_3 (100%)	425	458	510	590	621	681	637	690	605	580
Mean	373	398	436	480	512	546	512	569	485	479
Haulm yield (kg ha^{-1})										
M_1 (0)	395	415	460	485	505	564	540	573	560	500
M_2 (75%)	435	474	512	530	574	635	598	674	640	564
M_3 (100%)	502	530	570	605	655	798	711	803	770	665
Mean	444	473	514	540	578	655	609	714	657	576

	Pod yield (kg ha^{-1})				**Haulm yield (kg ha^{-1})**			
	M	S	M at S	S at M	M	S	M at S	S at M
SEd	3.49	7.64	12.96	13.24	4.23	9.06	15.40	15.70
CD (0.05)	9.66	15.37	26.77	26.62	11.85	18.22	31.87	31.56