Original Research Paper

Effect of N, Zn and B Levels on Yield, N, Zn and B Content and their Uptake and N Use Efficiency in Maize –Wheat Sequence in a Vertisol of Central India

ABSTRACT

A field experiment was conducted during 2010-12 at Research Farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (Madhya Pradesh) to study the effect of levels of N (0, 60, 120 and 180 kg ha^{-1}), Zn (0, and 10 kg ha^{-1}) and B (0 and 1.0 kg ha^{-1}) on yield, N, Zn and B content and their uptake and N use efficiency by maize and wheat in maize–wheat sequence in a Vertisol. The treatments of N were applied to maize and wheat crop. While the treatments of Zn and B were applied to only maize crop and their residual effect was observed in wheat crop. Application of increasing levels of N in maize and wheat significantly increased the yield, B content in grain and strover/straw and N, Zn and B uptake by maize and wheat over their respective control. The N application @ 120 and 180 kg ha^{-1} in wheat significantly increased the N, Zn and B content in grain and straw of wheat over control. The N use efficiency by maize and wheat significantly decreased with increasing levels of N.

The application of 10 kg Zn, 1.0 kg B and combined application of 10 kg Zn + 1.0 kg B and its residual effect significantly increased the grain yield, N uptake, Zn and B content in grain and their uptake by maize and wheat, respectively over control. The B application @ 1.0 kg ha^{-1} and its residual effect was found significantly superior to 10 kg Zn ha^{-1} for grain yield, B content in grain, N, Zn and B uptake by maize and wheat, respectively. The B application @ 1.0 kg ha^{-1} significantly increased the N use efficiency by maize over control.

Key words: *Uptake, N use efficiency, yield, Wheat, Zinc, Boron*

1. INTRODUCTION

In India, maize (*Zea mays* L.) and wheat (*Triticum aestivum* L.) are cultivated in 8.55 and 29.07 million ha with the production of 21.73 and 86.87 million tonnes having the productivity of 2540 and 2988 kg ha^{-1}, respectively. In Madhya Pradesh, maize and wheat are cultivated over an area of 0.83 and 4.34 million ha with the production of 1.05 and 14.93 million tonnes and productivity of 1265 and 1758 kg ha^{-1}, respectively during 2010-11 [1]. Maize is important in agricultural economy as food for man and feed for animal including poultry. It is a fast growing exhaustive crop require high amount of major nutrients (N and P) and micronutrient (Zn) to produce large biomass as its grain yield potential is twice as compared to other cereals crops [2]. The actual harvested yield of maize and wheat are low due to wide spread deficiency of N (89%) and Zn (49 %) and in-sufficient pre plant N and lack of Zn application as maize and wheat are highly and mildly sensitive to Zn deficiency, respectively [3-4]. N is the most important growth element and it is most frequently deficient nutrient in most non legume cropping system. The response of maize to N and Zn application has been reported by [4-5], respectively.

After Zn, B is the second yield limiting micronutrient (33 % deficient) which is essential for stimulating plant growth and in increasing yield of crops such as rice, wheat [6]. B and Zn deficiency upset the order of grains on the corn and make them deformed so that some parts of the corn ear are free from grain [7].The information on interaction among N, Zn and B is hardly available in maize – wheat sequence in the region hence the investigation was undertaken.

2. MATERIAL AND METHODS

A field experiment was conducted at Research Farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during 2010-12. The soils of the experimental site belongs to medium black clayey (Vertisol), pH 7.42, EC 0.16 dSm^{-1}, available N 164 $kgha^{-1}$, P 33.6 $kgha^{-1}$, K 200 $kgha^{-1}$,DTPA extractable Zn 1.18 mg kg^{-1} and hot water soluble B 0.49 mg kg^{-1}.The experiment was conducted in a split plot design comprised of 4 levels of N (0, 60, 120 and 180 $kgha^{-1}$) as main treatments and 2 levels of Zn (0 and 10 kg ha^{-1}) and 2 level of B (0 and 1 kg ha^{-1}) as sub treatments were replicated thrice. N levels were applied in three split doses. 50% of N treatment, 35.2 kg P, and 33.2 kg K $kgha^{-1}$were applied as basal dose through urea, single super phosphate and muriate of potash, respectively in maize and wheat crop. Zinc and boron levels were applied to maize crop as basal dose and their residual effect was observed in wheat crop. Remaining 25 % N each was applied at knee height and silking stage of maize and crown root initiation and maximum tillering stage of wheat. The maize crop (JM 216) was sown on 9.7 2010 and 5.7.2011 @ 20 kg ha^{-1} during first and second year respectively with spacing of 25 cm between plant to plant and 60 cm row to row. Two hand weeding were done on 10.08.2010 and 10.09.2010 during first year and 10. 08.2011 and 10.9.2011 during second year. The maize crop was harvested on 16.10 2010 and 22.10.2011.The rainfall received 1451.2 mm and 1525.1 mm during growth period of maize during 2010 and 2011, respectively. The wheat crop (GW-273) was sown on @ 120 kg ha^{-1} on dated 5.12.2010 and 23.11.2011 in the same field after the harvest of maize crop. Two hand weeding were done at 20 day interval after sowing of wheat crop. Four irrigations were applied to wheat crop at crown root initiation (CRI), tillering, flowering and seed formation stages of wheat. The wheat crop was harvested on 10.04.2011 and 7.04.2012.The plant samples of maize and wheat were collected at the time of harvesting for analysis of the nutrient content.The plant samples were washed with 0.1 N HCl and rinsed with distilled water and then dried at 60 ^{o}C for 6 - 8 hours. The samples were grinded by stainless steel blade grinder and then used for chemical analysis. N content in grain and stover was determined by micro-Kjeldahl method as described by [8]. The plant Zn content was determined after digestion of plant sample with diacid mixture of nitric and perchloric acid in 2.5:1 ratio suggested by [9] using atomic absorption spectrophotometer. Plant B content was determined by curcumin method as described by [10].The nutrient uptake was calculated by multiplying the nutrient content X yield. N use efficiency was estimated by=Increase in plant N uptake (kg ha^{-1}) due to N/Applied N level (kg ha^{-1}) X100.

3. RESULTS AND DISCUSSION

Maize yield

The pooled data presented in table 1 revealed that the increasing levels of N significantly increased the grain, stover and cob core yield of maize over control. However, the grain yield with 120 and 180 kg N ha^{-1} was found significantly superior to 60 kg N ha^{-1} but the difference between two N levels was found non-significant. While the stover and cob core yield successively and significantly increased with increasing levels of N. The increase of grain and stover yield of maize with increasing levels of N might be due to beneficial effect of N in vegetative growth, photosynthesis and in grain formation as N is a constituent of amino acid, protein and enzymes which are responsible for yield improvement. The increase of grain yield of maize with application of N was reported by [11-13].

The application of 10 kg Zn, 1.0 kg B and combined use of 10 kg Zn + 1 kg B ha^{-1} produced significantly higher grain yield. However, the grain, stover and cob core yield of maize with 1.0 kg B ha^{-1}was found significantly superior to 10 kg Zn alone and combined use of 10 kg Zn + 1.0 kg B ha^{-1}.The increase of grain, stover and cob core yield with Zn and B application might be due to beneficial effect of Zn and B on growth and yield of maize crop as Zn helps in enzyme activation, protection of bio membrane, hormone metabolism, nucleic acid, protein synthesis and seed formation.The interaction among N and Zn/B was found significant for grain and cob core yield of maize. The grain and cob core yield with the application of B @ 1.0 kg ha^{-1} was found significantly superior to 10 kg Zn alone or combined application of 10 kg Zn +1.0 kg B ha^{-1} with all N levels. The maximum grain yield of 4.65 t ha^{-1} was observed with 180 kg N +1.0 kg B ha^{-1} which was found significantly superior to lower levels of N. It might be due to synergistic effect of N and B application. The increase of grain yield with Zn application was reported by [14-18].The promotive effect of B may be due to maintain membrane integrity, pollen tube development which affects seed setting and ultimately the crop yield. The increase of yield of maize with B and Zn fertilizers was reported by [19-21].

N content and uptake by maize

The pooled data presented in table 1 and 2 revealed the application of N @ 120 kg ha^{-1} significantly increased the N content in grain and stover over control but the N level were found on par with higher or lower levels of N. The N uptake by grain, stover, cob core and total uptake significantly increased with increasing levels of N over control. However, the application of N @ 120 and 180 kg ha^{-1} were found significantly superior to 60 kg N ha^{-1} but the two N levels were found on par. The increase of N content in maize plant and its uptake with increasing levels of N might be due to increase of N availability in soil and which was taken up by plant. The increase of N content in and its uptake by maize with N application was confirmed by [22] and [13].

The application of 1.0 kg B alone and combined application of 10 kg Zn +1.0 kg B ha^{-1} were found significant over control for N content in stover. However, the 1.0 kg B ha^{-1} was found significantly superior to10 kg Zn ha^{-1} alone and combined use of 10 kg Zn +1.0 kg B ha^{-1} for N content in stover and

N uptake by grain, stover, cob core and total N uptake by maize. The interaction among N, Zn and B was found significant for N content in grain and its uptake. The combined application of 10 kg Zn+1.0 kg B ha^{-1} was found significant over 10 kg Zn and 1.0 kg B alone at 120 kg N ha^{-1}. While N content in stover with 1.0 kg B ha^{-1} was found significant over 10 kg Zn alone but it was found on par with combined application of 10 kg Zn +1.0 kg B ha^{-1}.The N uptake by grain, stover, cob core and total N uptake by maize with 1.0 kg Bha^{-1} was found significantly superior to 10 kg Zn alone or combined application of 10 kg Zn +1.0 kg B ha^{-1} with 60, 120 and 180 kg N ha^{-1} except N uptake by grain and stover with combined application of 10 kg Zn +1.0 kg B ha^{-1} at 120 kg N ha^{-1}. The N content in grain and its uptake by grain significantly increased with the application of Zn and B alone and combined application of 10 kg Zn +1.0 kg B ha^{-1}. The increase of N content in and its uptake by grain, stover, cob core and total N uptake by maize due to beneficial effect of Zn and B increasing the availability of N in soil. The increase of N content in and N uptake by maize due to Zn or B application was supported by [15], [23] and [24].

N use efficiency by Maize

The data presented in table 3 revealed that the application of N @ 60,120 and 180 kg ha^{-1} resulted N recovery of 54.77, 48.20 and 35.31% by maize crop, respectively which decreased significantly with increasing levels of N. This decreased N use efficiency might be due to increase of N losses with increasing levels of N and improportionate increase of N uptake by maize. Similar results of N use efficiency in maize crop reported by [12].

The application of 1.0 kg B and combined use of 10 kg Zn +1.0 kg B ha^{-1}significantly increased the N use efficiency over control and 10 kg Zn ha^{-1}. However, the N use efficiency with 1.0 kg B (59.74%) was found significantly higher than that at 10 kg Zn +1kg B ha^{-1}. The interaction among N, Zn and B was found significant. The N use efficiency with the application of 1.0 kg B and conjoint use of 10 kg Zn +1.0 kg B ha^{-1} at 60 and 120 kg N ha^{-1} was found significantly superior to control or 10 kg Zn alone. The maximum N use efficiency 75.24 % was observed with 1.0 kg B + 60 kg N ha^{-1} which decreased significantly with 120 and 180 kg N ha^{-1}. The increase of N use efficiency with B application might be due to beneficial effect of B application on increase of N uptake (table 3). The increase of N use efficiency with B application was also reported by [22] and [20].

Zn content and uptake by maize

The pooled data presented in table 1 indicated that the maximum Zn content in stover 29.02 mg kg^{-1} was observed in control but it significantly decreased with 60/120 and 180 kg Nha^{-1}. The Zn content in stover with 60 and 120 kg N ha^{-1} was found on par. The Zn uptake by grain, stover, cob core and total Zn uptake by maize significantly increased with increasing levels of N over control. However, the Zn uptake by grain successively and significantly increased with increasing levels of N. While the Zn uptake by stover, cob core and total Zn uptake by maize with120 and 180 kg N ha^{-1} were found significantly superior to 60 kg N ha^{-1} except Zn uptake by stover with 180 kg N ha^{-1} but the difference between two treatment was found non-significant. The decrease of Zn content in plant with higher N levels might be due to dilution of Zn as a result of increased plant growth with higher N levels.The increased N uptake by maize with N application might be due to higher dry matter yield with N application. These results are in agreement with [12].

The application of 10 kg Zn, 1.0 kg B and combined use of 10 kg Zn + 1.0 kg B ha^{-1} significantly increased the Zn content in grain, stover, cob core and their Zn uptake over control except Zn content in stover with 1.0 kg B ha^{-1}. However, the Zn content in grain, stover and cob core with 10 kg $Znha^{-1}$ and combined use of 10 kg Zn +1.0 kg Bha^{-1} were found significantly superior to 1.0 kg B ha^{-1}but the difference between the two treatment was found not significant for Zn content in grain and cob core. However, the Zn content in stover with combined application of 10 kg Zn +1.0 kg B ha^{-1} was found significantly superior to 10 kg Zn ha^{-1} alone. It might be due to beneficial effect of Zn application in increasing the availability of Zn in soil and accumulated in plant and increased grain and stover yield of maize resulted higher Zn uptake. While the Zn uptake by grain and cob core with 1.0 kg B ha^{-1}alone and combined application of 10 kg Zn +1.0 kg B ha^{-1} were found significantly superior to 10 kg Zn ha^{-1} alone but the difference between the two treatment was found non-significant for Zn uptake by grain.Whereas the Zn uptake by stover and total Zn uptake by maize with combined application of 10 kg Zn +1.0 kg B $ha^{-1}$was also found significantly superior to 10 kg Zn and 1.0 kg B ha^{-1} alone. The interaction among N, Zn and B was found significant for Zn content and uptake. The application of 10 kg $Znha^{-1}$ alone and combined use of 10 kg Zn +1.0 kg B ha^{-1} with 60 and 120 kg N ha^{-1} were found significant over 1.0 kg B ha^{-1} for Zn content in grain, stover and cob core except Zn content in cob core at 60 kg N ha^{-1}. The maximum Zn content in grain 36.41 mg kg^{-1} and stover 35.36 mg kg^{-1} was observed with combined application of 10 kg Zn+ 1.0 kg B ha^{-1} at 60 and 0 N, respectively which decreased significantly with 180 kg N ha^{-1}. While the Zn uptake by grain with 1.0 kg B ha^{-1} progressively and significantly increased with N levels over 10 kg Zn alone. While the combined application of 10 kg Zn +1.0 kg B ha^{-1} at 120 kg N ha^{-1} level was found significantly superior to 60 kg N ha^{-1}. The Zn uptake by stover and total Zn uptake by maize was found significantly higher with 10 kg Zn ha^{-1} at 120 kg Nha^{-1} than that of 1.0 kg B or combined application of 10 kg Zn +1.0 kg B with lower or higher level of N. The significant increase of Zn content in and Zn uptake by maize with B and Zn fertilization was reported by [15] and [23-24].

B content and uptake by maize

The pooled data presented in table 1 revealed that the increasing levels of N significantly increased the B content in grain, stover and cob core over control but the treatments were found on par amongst themselves for B content in grain and stover. While the B content in cob core with 120 and 180 kg N ha^{-1} was found significantly higher than that at 60 kg N ha^{-1} but the difference between the two level was found non-significant. However, B uptake by grain, stover, cob core and total B uptake by maize successively and significantly increased with increasing levels of N. An increase in B content in plant tissue as a result of B application is obviously due to enhanced availability of B in soil and subsequently its uptake by plant. These results are in agreement with the findings of [25].The application of 10 kg Zn, 1.0 kg B and combined use of 10 kg Zn+1.0 kg B ha^{-1} significantly increased the B content in grain and cob core as well as B uptake by grain, stover, cob core and total B uptake by maize over control but the treatments were found on par amongst themselves for B uptake by stover. However, the B content in grain and their uptake with 1.0 kg B ha^{-1} was found significantly superior to10 kg Zn ha^{-1}alone and combined application of 10 kg Zn +1.0 kg B ha^{-1}. Whereas the B content in stover was found significantly higher with combined application of 10 kg Zn +1.0 kg B ha^{-1} than control. The interaction among N, Zn and B was found significant for B content in grain, stover, cob core and their B uptake by maize. The B content in grain and cob core and their uptake with 1.0 kg B ha^{-1} was found significantly superior to 10 kg Zn ha^{-1} alone and combined use of 10 kg Zn +1.0 kg B ha^{-1}at all N levels except B content in cob core with combined use of 10 kg Zn+1kg B ha^{-1}at 120 and 180 kg N ha^{-1}.The B content in grain with 1.0 kg B +120 kg N ha^{-1}was found significantly superior to combined application of 10 kg Zn + 1.0 kg B ha^{-1} at 60 or 180 kg N ha^{-1}. The B content in stover was found significantly higher than 10 kg Zn and 1.0 kg B ha^{-1}at 60 kg N ha^{-1}. While it was found significant with 1.0 kg B+180 kg N ha^{-1} than combined application of 10 kg Zn+1.0 kg B ha^{-1}.The B uptake by grain with 1.0 kg B +120 kg N ha^{-1} was found significantly superior to 1.0 kg B +60 kg N ha^{-1} but it was found on par with 180 kg Nha^{-1}. The B uptake by stover and total B uptake by maize with 1.0 kg B ha^{-1} alone successively and significantly increased with increasing levels of N. The maximum B uptake by stover and total B uptake by maize was observed with1 kg B +180 kg N ha^{-1} which was significantly higher than combined application of 10 k g Zn+1.0 kg B ha^{-1}. The application of Zn and B increased the B uptake by maize was reported by [26].

Wheat yield

The pooled data presented in table 4 revealed that the grain and straw yield significantly increased with increasing levels of N over control. However, the grain yield with N @ 120 and 180 kg ha^{-1} was found significantly superior to 60 kg N ha^{-1} but the difference between the two N level was found non significant. While the straw yield with 180 kg N ha^{-1} was found significantly higher than that at 60 or 120 kg N ha^{-1} but the N @60 and 120 kg ha^{-1} were found at par. The increase of grain and straw yield of wheat with increasing levels of N due to beneficial effect of N in better root growth higher N content and uptake. The increase of wheat yield with N application was reported by [27-28].

The residual effect of 10 kg Zn, 1.0 kg B and combined use of 10 kg Zn+1.0 kg B ha^{-1} significantly increased the grain and straw yield of wheat over control but the treatments were found on par amongst themselves for straw yield of wheat. However, the grain yield with residual effect of 1.0 kg B was found significantly higher than that of 10 kg Zn ha^{-1} but it was found on par with residual effect of combined application of 10 kg Zn+1kg Bha^{-1}. The increase of grain and straw yield of wheat due to beneficial effect of residual Zn and B in soil.The interaction among N, Zn and B was found significant for grain and straw yield. The grain and straw yield with residual effect of B @ 1.0 kg ha^{-1} was found significantly superior to the residual effect of combined application of 10 kg Zn +1.0 kg B ha^{-1} at 120 kg N ha^{-1}. The treatment was also found significantly superior to 60 kg N ha^{-1} but it was found on par with higher levels of N. The increase of wheat yield due to residual effect of Zn was reported by [15], [18] and [29-34] reported increase of yield of wheat with B application.

N content and uptake by wheat

The pooled data presented in table 4 and 5 revealed that the application of the increasing levels of N significantly increased the N content in grain, straw and their N uptake and total N uptake by wheat over control except N content in grain with 60 kg N ha^{-1}. The N uptake by grain, straw and total N uptake by wheat followed the same trend. However, the N content in straw and N uptake by grain and straw and total N uptake with 120 and 180 kg N ha^{-1}were found significantly superior to 60 kg N ha^{-1}but the difference between the two treatment was found non significant. Consistently positive effect of N application on its content and uptake could be due to the increased availability of N in the soil with N application which resulted in greater absorption of N by plant due to better vegetative growth and root development. Similar results were recorded by [35] and [27].

The residual effect of 1.0 kg B ha^{-1} and combined application of 10 kg Zn +1 kg B ha^{-1} significantly increased the N content in grain and straw , respectively over control but other treatments were found non significant over control. These treatments significantly increased the N uptake by grain, straw and total N uptake by wheat over control except N uptake by straw with 10 kg Zn alone. However, the N uptake by grain with residual effect of 1.0 kg B ha^{-1} was found significantly superior to residual effect of 10 kg Zn ha^{-1} alone. The interaction among N, Zn and B were found significant for total N uptake by wheat.The total N uptake by wheat with residual effect of 1.0 kg B ha^{-1} was found significantly superior to residual effect of 10 kg Znha^{-1} at 60 and 120 kg N ha^{-1}. The maximum N uptake 163.88 kg N ha^{-1} was observed with residual effect of combined use of 10 kg Zn +1.0 kg B ha^{-1} at 120 kg N ha^{-1} which was also found significantly higher than that of 1.0 kg B ha^{-1}at 60 kg N ha^{-1}.The increased N content in grain and straw of wheat with residual effect of 1.0 kg B ha^{-1} and combined use of 10 kg Zn+1.0 kg B might be due to beneficial effect of Zn and B in increasing N availability in soil and resulted higher N content and uptake by wheat. These results are in agreement with [15].

N use efficiency by wheat

The data presented in table 5 indicated that the application of N @ 60,120 and 180 kg N ha^{-1} resulted N recovery of 69.69, 56.87 and 40.83 %, respectively which decreased significantly with increasing levels of N in wheat. The maximum recovery of N was observed at lower level of 60 kg N ha^{-1} and minimum at higher level of N @180 kg ha^{-1}.This decreased N use efficiency might be due to increased N losses and improportionate increased N uptake by wheat with increasing levels of N as a result of decreased total dry matter production and competition among plant for N due to more available N in soil. The decrease of recovery efficiency of N in wheat with increasing levels of N was reported by [35].

The residual effect of B @ 1.0 kgha^{-1} significantly increased the N recovery over residual effect of 10 kg Zn ha^{-1} but it was found on par with the residual effect of conjoint use of 10 kg Zn +1.0 kg B ha^{-1}. The increase of N use efficiency with B application might be due to beneficial effect of B application on increase of N uptake by wheat (Table 5). The interaction among N, Zn and B was found significant. The residual effect of B @ 1.0 kg ha^{-1} was found significantly superior to residual effect of combined application of 10 kg Zn +1kg B at 120 kg N ha^{-1} but it was found on par with 10 kg Zn alone. The N use efficiency with 1kg B +120 kg N ha^{-1} was found significantly superior to 180 kg N +1.0 kg B ha^{-1}. The increase of N use efficiency with B application was reported by [20].

Zn content and uptake by wheat

The pooled data presented in table 4 and 5 revealed that the application of N @120 and 180 kg ha^{-1} significantly increased the Zn content in grain and straw of wheat over control but the difference between the two N level was found non significant. However, the Zn uptake by grain, straw and total Zn uptake of wheat progressively and significantly increased with increasing levels of N. The increase of Zn content and uptake by wheat might be due to beneficial effect of N application in increasing the Zn availability in soil due to decrease in pH. These results are supported by [36].

The residual effect of 10 kg Zn, 1.0 kg B and combined use of 10 kg Zn +1.0 kg B ha^{-1} significantly increased the Zn content in grain, straw and their Zn uptake as well as total Zn uptake by wheat over control except Zn content in grain with 1.0 kg B ha^{-1}. However, the Zn content in grain with residual effect of 10 kg Zn ha^{-1} and combined use of 10 kg Zn +1.0 kg B ha^{-1} were found significantly superior to residual effect of 1 kg B ha^{-1} but the two treatments were found on par. While the residual effect of combined application of 10 kg Zn +1 kg B ha^{-1}was also found significantly superior to residual effect of 1.0 kg B for Zn content in grain and straw and its Zn uptake and total Zn uptake by wheat but it was found on par with 10 kg Zn ha^{-1}.The increase of Zn content and uptake by wheat might be due to beneficial effect of residual Zn level in increasing the Zn availability in soil and resulted higher Zn uptake by wheat. The residual effect of Zn increased the Zn content and its uptake by wheat was also reported by [15] and [30-32].

B content and uptake by wheat

The pooled data presented in table 4 and 5 revealed that the increasing levels of N significantly increased the B content in grain and straw and their B uptake by wheat over control but the treatments were found on par amongst themselves for B content in grain and straw. However, the B uptake by grain, straw and total B uptake by wheat with N @ 120 and 180 kg ha^{-1} was found significantly superior to N @ 60 kg ha^{-1} but the difference between the two treatment was found non significant. The significant increase of B uptake with application of N was reported by [32].

The residual effect of 10 kg Zn, 1.0 kg B and combined use of 10 kg Zn +1.0 kg B ha^{-1} significantly increased the B content in and Zn uptake by grain and straw and total B uptake by wheat over control except B content in straw with 10 kg Zn ha^{-1}. However, the B content in grain and straw and its B uptake and total B uptake with residual effect of 1.0 kg B ha^{-1} and combined use of 10 kg Zn +1.0 kg B ha^{-1} were found significantly superior to10 kg Zn ha^{-1} except B content in straw with 10 kg Zn +1.0 kg B ha^{-1}. The total B uptake by wheat with residual effect of 1.0 kg B ha^{-1} was also found significantly superior to the residual effect of combined application of 10 kg Zn + 1.0 kg B ha^{-1}. The interaction between N and Zn/B was found significant for B content in grain and B uptake by straw. B content in grain and B uptake by straw with residual effect of 1.0 kg B was found significantly superior to residual effect of 10 kg Zn alone as well as Zn uptake by straw over combined use of 10 kg Zn +1kg B ha^{-1} at 120 and 180 kg N ha^{-1}.The increase of B content and uptake with B application was reported by [34].

4. CONCLUSIONS

The application of 120 kg N + 1.0 kg B ha^{-1} produced the maximum grain yield (4.18 t ha^{-1}) of maize and addition of 120 N ha^{-1} alone in wheat gave the maximum grain yield of wheat (5.9 t ha^{-1}) in maize-wheat sequence. The maximum N and B content in grain and their uptake and recovery efficiency of N was observed with 1.0 kg B+120 kg N ha^{-1} in maize-wheat sequence.

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Table 1. Effect of N, Zn and B levels on yield and N, Zn and B content in maize (pooled data of 2010 and 2011)

		Yield (tha^{-1})								N content (%)							
Treatments	Main/Sub	N0	N60	N120	N180	Mean		Sem	CD	N0	N60	N120	N180	Mean		Sem	CD
Grain	Zn0B0	0.75	1.32	2.49	2.42	1.75	N levels	0.062	0.19	0.98	1.11	1.13	0.92	1.04	N levels	0.022	0.068
	Zn10B0	1.12	1.75	2.6	3.3	2.19	Zn/B	0.054	0.153	1.06	1.15	1.12	1.07	1.1	Zn/B	0.019	NS
	Zn0B1	1.97	3.08	4.18	4.65	3.47	NXZn/B(1)	0.107	0.305	1.04	1.15	1.1	1.05	1.09	NXZn/B(1)	0.039	0.11
	Zn10B1	1.88	2.43	3.36	3.79	2.86	NXZn/B(2)	0.142	0.403	0.83	1.15	1.24	1.07	1.07	NXZn/B(2)	0.051	0.145
	Mean	1.43	2.15	3.16	3.54	2.57				0.98	1.14	1.15	1.03	1.07			
Stover	Zn0B0	4.51	7.11	7.78	9.67	7.26	N levels	0.246	0.759	0.6	0.6	0.61	0.51	0.58	N levels	0.011	0.061
	Zn10B0	4.42	7.47	8.66	9.98	7.63	Zn/B	0.181	0.516	0.55	0.55	0.58	0.71	0.6	Zn/B	0.008	0.023
	ZnB1	5.1	7.95	9.6	10.12	8.19	NXZn/B(1)*	0.362	NS	0.66	0.75	0.77	0.77	0.74	NXZn/B(1)	0.016	0.046
	Zn10B1	4.69	7.37	8.56	9.89	7.63	NXZn/B(2)**	0.529	NS	0.61	0.63	0.76	0.57	0.64	NXZn/B(2)	0.023	0.066
	Mean	4.68	7.47	8.65	9.92	7.68				0.61	0.63	0.68	0.64	0.64			
Cob core	Zn0B0	0.29	1.05	1.51	1.84	1.17	N levels	0.055	0.169	0.34	0.42	0.42	0.45	0.41	N levels	0.014	NS
	Zn10B0	0.95	1.25	2.02	2.04	1.57	Zn/B	0.053	0.15	0.43	0.44	0.47	0.43	0.44	Zn/B	0.013	NS
	ZnB1	1.63	2.97	3.32	3.19	2.78	NXZn/B(1)	0.106	0.301	0.46	0.4	0.47	0.45	0.45	NXZn/B(1)	0.027	NS
	Zn10B1	0.97	2.39	2.29	2.89	2.14	NXZn/B(2)	0.132	0.376	0.39	0.36	0.42	0.47	0.41	NXZn/B(2)	0.034	NS
	Mean	0.96	1.91	2.29	2.49	1.91				0.41	0.41	0.45	0.45	0.43			
		Zn content (mg kg^{-1})								B content (mg kg^{-1})							
Grain	Zn0B0	24.8	26.6	30.2	29.44	27.8	N levels	0.922	NS	5.34	7.28	7.7	7.88	7.05	N levels	0.145	0.448
	Zn10B0	33.7	34.8	31.2	30.14	32.5	Zn/B	0.519	1.477	5.15	8.03	8.56	8.88	7.65	Zn/B	0.13	0.37
	Zn0B1	30.9	29.3	25.9	30.28	29.1	NXZn/B(1)*	1.037	2.954	9.3	10.4	11.2	10.7	10.4	NXZn/B(1)	0.26	0.737
	Zn10B1	34.6	36.4	33.9	30.64	33.9	NXZn/B(2)**	1.833	5.22	7.82	9.7	9.58	9.04	9.03	NXZn/B(2)	0.338	0.958
	Mean	31	31.8	30.3	30.12					6.9	8.86	9.26	9.12	8.53			
Stover	Zn0B0	25.9	20.1	21.5	20.07	21.9	N levels	0.596	1.838	10.7	15	15.8	16.4	14.5	N levels	0.378	1.166
	Zn10B0	26.8	28.8	32.8	22.93	27.9	Zn/B	0.549	1.562	12	15.2	15.7	18.2	15.3	Zn/B	0.336	0.957
	Zn0B1	28	22.4	23.5	18.52	23.1	NXZn/B(1)*	1.097	3.125	14	14.3	15.4	17.6	15.3	NXZn/B(1)	0.672	1.914
	Zn10B1	35.4	35.3	28.9	24.44	31	NXZn/B(2)**	1.403	3.997	16	18	17	13.4	16.1	NXZn/B(2)	0.876	2.496
	Mean	29	26.7	26.7	21.49					13.2	15.6	16	16.4	15.3			
Cob core	Zn0B0	23.3	23.5	19.9	26.24	23.2	N levels	0.538	NS	1.68	2.78	3.23	3.92	2.9	N levels	0.069	0.212
	Zn10B0	32.6	30.2	32.3	30.22	31.3	Zn/B	0.503	1.432	2.85	3.94	4.54	4.49	3.95	Zn/B	0.049	0.139
	Zn0B1	26.4	28.4	28	27.44	27.6	NXZn/B(1)*	1.006	2.865	3.39	5.01	4.75	4.89	4.51	NXZn/B(1)	0.098	0.278
	Zn10B1	32.2	30.9	31.7	28.97	30.9	NXZn/B(2)**	1.276	3.633	4.2	4.41	4.94	4.62	4.54	NXZn/B(2)	0.146	0.416
	Mean	28.6	28.3	28	28.22					3.03	4.03	4.36	4.48	3.98			

* Comparison of two Zn/B levels at same level of N   **comparison of two N levels at same or different levels of Zn/B

Table 2. Effect of N, Zn and B levels on N and Zn uptake by maize (pooled data of 2010 and 2011)

Treatments		N uptake (kg ha^{-1})								Zn uptake (g ha^{-1})							
	Main/Sub	N0	N60	N120	N180	Mean		Sem	CD	N0	N60	N120	N180	Mean		Sem	CD
Grain	Zn0B0	7.45	14.72	28.35	21.63	18.04	N levels	0.971	2.993	18.93	36.34	74.4	71.12	50.2	N levels	3.386	10.407
	Zn10B0	11.77	20.11	27.84	33.39	23.28	Zn/B	0.82	2.336	37.54	61.84	80.84	98.47	69.67	Zn/B	2.096	5.952
	Zn0B1	20.37	35.37	45.94	48.67	37.59	NXZn/B(1)*	1.641	4.673	58.46	87.84	107.97	141.38	98.91	NXZn/B(1)	4.191	11.901
	Zn10B1	16.31	27.87	41.9	40.13	31.55	NXZn/B(2)**	2.201	6.27	64.43	88.18	113.43	114.8	95.21	NXZn/B(2)	6.896	19.583
	Mean	13.98	24.52	36.01	35.95					44.84	68.55	94.16	106.44				
Stover	Zn0B0	27.07	42.01	46.64	47.36	40.77	N levels	1.992	6.141	132.96	157.13	183.48	217.37	172.73	N levels	7.102	21.83
	Zn10B0	24.14	40.27	48.43	71.18	46	Zn/B	1.481	4.217	125.27	226.11	305.81	249.66	226.71	Zn/B	6.933	19.688
	Zn0B1	33.05	58.62	71.32	76.42	59.85	NXZn/B(1)*	2.961	8.434	168.43	192.04	243.36	202.43	201.56	NXZn/B(1)	13.865	39.373
	Zn10B1	28.83	46.86	63.28	53.91	48.22	NXZn/B(1)**	2.961	8.434	180.45	287.58	259.66	263.27	247.74	NXZn/B(2)	17.19	48.815
	Mean	28.27	46.99	57.42	62.22					151.77	215.72	248.08	233.18				
Cob core	Zn0B0	0.99	4.67	7.22	9.07	5.49	N levels	0.526	1.621	6.74	25.4	26.8	46.2	26.3	N levels	1.853	5.712
	Zn10B0	4.13	5.73	10.2	8.98	7.26	Zn/B	0.38	1.08	31.2	39	65.4	59.4	48.8	Zn/B	1.9	5.4
	Zn0B1	7.2	11.8	15.6	14.3	12.2	NXZn/B(1)*	0.76	2.16	40.9	83.2	92.6	87.5	76	NXZn/B(1)	3.79	10.8
	Zn10B1	3.83	8.59	9.78	14.3	9.12	NXZn/B(2)**	1.12	3.2	29.7	74.2	72.8	82.6	64.8	NXZn/B(2)	4.59	13.1
	Mean	4.04	7.7	10.7	11.7					27.2	55.5	64.4	68.9				
Total	Zn0B0	35.5	61.4	82.2	78.1	64.3	N levels	2.274	7.013	159	219	285	335	249	N levels	8.89	27.4
	Zn10B0	40	66.1	86.5	114	76.5	Zn/B	1.94	5.53	194	327	452	408	345	Zn/B	8.33	23.7
	Zn0B1	60.6	106	133	139	110	NXZn/B(1)*	3.88	11.1	268	363	444	431	377	NXZn/B(1)	16.7	47.4
	Zn10B1	49	83.3	115	108	88.9	NXZn/B(2)**	5.18	14.7	275	450	446	461	408	NXZn/B(2)	21.1	60.1
	Mean	46.3	79.2	104	110					224	340	407	409				

* Comparison of two Zn/B levels at same level of N

**comparison of two N levels at same or different levels of Zn/B

Table 3. Effect of N, Zn and B levels on N use efficiency and B uptake by maize (pooled data of 2010 and 2011)

		B uptake (g ha^{-1})								N Use Efficiency (%)							
Treatments	Main/Sub	N0	N60	N120	N180	Mean		Sem	CD	Zn0B0	N60	N120	N180	Mean		Sem	CD
Grain	Zn0B0	3.84	9.22	18.26	18.54	12.47	N levels	0.659	2.026	Zn10B0	43.17	38.91	23.64	35.24	N levels	1.95	6.01
	Zn10B0	5.75	13.76	21.71	28.07	17.32	Zn/B	0.771	2.189	Zn0B1	43.43	38.68	40.84	40.98	Zn/B	2.2402	6.3807
	Zn0B1	19.23	32.8	47.14	49.72	37.22	NXZn/B(1)*	1.541	4.376	Zn10B1	75.24	60.22	43.75	59.74	NXZn/B(1)	4.48	12.76
	Zn10B1	15.02	23.5	31.66	33.75	25.98	NXZn/B(2)**	1.756	4.987	Mean	57.26	54.99	33	48.42	NXZn/B(2)	5.145	14.654
	Mean	10.96	19.82	29.69	32.52	23.25					54.77	48.2	35.31				
Stover	Zn0B0	46.1	108.1	126.3	164.3	111.2	N levels	5.174	15.9								
	Zn10B0	49.73	113.8	138.7	191.4	123.4	Zn/B	3.466	9.843								
	Zn0B1	70.56	109.5	141.5	183.5	126.2	NXZn/B(1)*	6.932	19.66								
	Zn10B1	78.79	138.3	149	123.8	122.5	NXZn/B(2)**	10.79	30.63								
	Mean	61.3	117.4	138.9	165.8	120.8											
Cob core	Zn0B0	0.49	2.9	4.94	7.16	3.87	N levels	0.295	0.91								
	Zn10B0	2.71	4.87	9.3	9.06	6.48	Zn/B	0.24	0.7								
	Zn0B1	5.61	14.9	15.7	15.6	13	NXZn/B(1)*	0.49	1.39								
	Zn10B1	4.15	10.5	11.3	13.3	9.82	NXZn/B(2)**	0.66	1.89								
	Mean	3.24	8.3	10.3	11.3												
Total	Zn0B0	50.4	120.2	149.5	190	127.5	N levels	5.44	16.77								
	Zn10B0	58.2	132.4	169.7	228.5	147.2	Zn/B	3.77	10.75								
	Zn0B1	95.4	157.1	204.3	248.8	176.4	NXZn/B(1)*	7.55	21.5								
	Zn10B1	98	172.3	192	170.8	158.3	NXZn/B(2)**	11.47	32.67								
	Mean	75.5	145.5	178.9	209.6												

* Comparison of two Zn/B levels at same level of N

**comparison of two N levels at same or different levels of Zn/B

Table 4.Direct effect of N and residual effect of Zn and B levels on yield and N, Zn and B content in wheat (pooled data of 2010 and 2011)

		Wheat yield (t ha^{-1})								N content (%)							
Treatments	Main/Sub	N0	N60	N120	N180	Mean		Sem	CD	N0	N60	N120	N180	Mean		Sem	CD
Grain	Zn0B0	2.94	4.35	5.32	5.6	4.55	N levels	0.079	0.244	1.44	1.54	1.68	1.7	1.59	N levels	0.04	0.125
	Zn10B0	3.54	4.77	5.57	5.85	4.93	Zn/B	0.061	0.174	1.53	1.61	1.82	1.85	1.7	Zn/B	0.026	0.073
	Zn0B1	3.66	5.25	5.9	5.85	5.16	NXZn/B(1)*	0.122	0.348	1.59	1.67	1.84	1.83	1.73	NXZn/B(1)	0.051	NS
	Zn10B1	3.73	5.25	5.55	5.72	5.06	NXZn/B(2)**	0.173	0.493	1.51	1.65	1.8	1.71	1.67	NXZn/B(2)	0.083	NS
	Mean	3.47	4.91	5.58	5.75					1.52	1.62	1.78	1.77	1.67			
Straw	Zn0B0	4.36	6.67	7.53	8.66	6.81	N levels	0.196	0.604	0.42	0.56	0.59	0.6	0.54	N levels	0.011	0.034
	Zn10B0	5.24	7.43	7.85	8.52	7.26	Zn/B	0.111	0.315	0.47	0.57	0.59	0.63	0.56	Zn/B	0.012	0.034
	Zn0B1	5.13	7.65	8.46	8.56	7.45	NXZn/B(1)*	0.221	0.63	0.51	0.57	0.66	0.66	0.6	NXZn/B(1)	0.024	NS
	Zn10B1	5.74	7.37	7.49	8.63	7.31	NXZn/B(2) **	0.39	1.11	0.47	0.59	0.6	0.63	0.58	NXZn/B(2)	0.028	NS
	Mean	5.12	7.28	7.83	8.6					0.47	0.57	0.61	0.63	0.57			
		Zn content (mg kg^{-1})								B content(mg kg^{-1})							
Treatments	Main/Sub	N0	N60	N120	N180	Mean		Sem	CD	N0	N60	N120	N180	Mean		Sem	CD
Grain	Zn0B0	23.87	25.32	25.9	26.72	25.45	N levels	0.465	1.324	8.36	14.94	15.02	13.71	13.01	N levels	0.41	1.265
	Zn10B0	27.31	28.21	28.35	27.78	27.91	Zn/B	0.388	1.106	10.74	15.33	15.71	15.98	14.44	Zn/B	0.337	0.959
	Zn0B1	24.74	26.05	25.72	26.91	25.86	NXZn/B(1)*	0.777	NS	14.4	16.17	17.99	18.31	16.72	NXZn/B(1)	0.673	1.918
	Zn10B1	26.91	28.21	28.74	30.1	28.49	NXZn/B(2)**	1.049	NS	15.72	17.47	17.68	17.78	17.16	NXZn/B(2)	0.919	2.618
	Mean	25.71	26.94	27.17	27.88					12.31	15.98	16.6	16.44				
Straw	Zn0B0	8.14	8.35	8.58	9.24	8.58	N levels	0.264	0.814	5.38	6.84	7.81	7.44	6.87	N levels	0.305	0.941
	Zn10B0	9.39	9.74	10.23	10.53	9.97	Zn/B	0.183	0.521	5.78	8.07	8.11	7.83	7.44	Zn/B	0.267	0.76
	Zn0B1	8.95	9.24	9.39	10.46	9.51	NXZn/B(1)*	0.366	NS	7.98	9.34	10.25	9.6	9.29	NXZn/B(1)	0.533	NS
	Zn10B1	9.18	9.86	11.28	11.28	10.4	NXZn/B(2)**	0.556	NS	6.89	9.14	8.7	7.84	8.14	NXZn/B(2)	0.702	NS
	Mean	8.91	9.3	9.87	10.38					6.51	8.35	8.72	8.18				

* Comparison of two Zn/B levels at same level of N
**comparison of two N levels at same or different levels of Zn/B

Table 5.Direct effect of N and residual effect of Zn and B levels on NUE and N, Zn and B uptake by wheat (pooled data of 2010 and 2011)

Treatments		**N uptake by (kg ha^{-1})**								**Zn uptake (g ha^{-1})**							
	Main/Sub	N0	N60	N120	N180	Mean		SEm±	CD(P=0.05)	N0	N60	N120	N180	Mean		Sem	CD
Grain	Zn0B0	42.68	67.08	89.79	95.1	73.75	N levels	3.143	9.692	69.76	109.7	137.8	149.7	116.8	N levels	2.47	7.592
	Zn10B0	53.64	76.89	101.5	109.6	85.17	Zn/B	1.624	4.695	95.32	134	157.6	162	137.2	Zn/B	2.644	7.508
	Zn0B1	57.78	87.25	108.4	107	90.11	NXZn/B(1)*	3.248	NS	89.3	136.4	151.1	156.9	133.4	NXZn/B(1)	5.287	NS
	Zn10B1	56.56	87.58	100.5	98.18	85.72	NXZn/B(2)**	6.129	NS	98	147.5	159.1	172.1	144.2	NXZn/B(2)	6.266	NS
	Mean	52.66	79.71	100	102.4					88.1	131.9	151.4	160.2	132.9			
Straw	Zn0B0	22.13	38.41	44.7	48.69	38.48	N levels	1.318	4.063	35.89	55.62	64.52	79.71	58.94	N levels	1.732	5.324
	Zn10B0	28.8	42.29	45.8	49.92	41.7	Zn/B	1.141	3.249	49.15	72.25	80.37	89.81	72.89	Zn/B	1.663	4.722
	Zn0B1	28.81	42.29	55.5	53.91	45.13	NXZn/B(1)*	2.293	NS	45.78	70.21	79.34	87.28	70.65	NXZn/B(1)	3.327	NS
	Zn10B1	28.17	44.04	45.42	50.58	42.06	NXZn/B(2)**	3.04	NS	52.68	72.73	84.61	95.96	76.5	NXZn/B(2)	4.159	NS
	Mean	26.98	41.76	47.86	50.78	41.85				45.88	67.7	77.21	88.19	69.74			
Total	Zn0B0	64.81	105.5	134.5	143.8	112.1	N levels	3.84	11.84	105.7	165.4	202.3	229.4	175.7	N levels	2.834	8.071
	Zn10B0	82.44	119.2	147.3	159.3	127	Zn/B	1.753	4.993	144.5	206.3	237.9	251.8	210.1	Zn/B	3.128	8.91
	Zn0B1	86.59	129.6	163.9	160.9	135.2	NXZn/B(1)*	3.506	9.985	135.1	206.6	230.5	244.2	204.1	NXZn/B(1)	6.256	NS
	Zn10B1	84.75	131.6	145.9	148.8	127.8	NXZn/B(2)**	7.331	20.82	150.7	220.2	243.8	268.1	220.7	NXZn/B(2)	7.311	NS
	Mean	79.65	121.5	147.9	153.2					134	199.6	228.6	248.4	202.6			
		B uptake(g ha^{-1})								**N use efficiency (%)**							
Grain	Zn0B0	24.12	65.43	80.03	77.58	61.79	N levels	2.858	8.785	Zn0B0	N60	N120	N180	Mean		SEm±	CD(P=0.05)
	Zn10B0	37.64	73.15	87.19	93.7	72.92	Zn/B	2.058	5.844	Zn10B0	67.8	58.08	43.88	56.59	N levels	2.651	8.174
	Zn0B1	52.23	84.45	106.6	107	87.57	NXZn/B(1)*	4.115	NS	Zn0B1	61.18	54.02	42.58	52.59	Zn/B	2.258	6.43
	Zn10B1	58.98	91.65	97.89	101.8	87.57	NXZn/B(2)**	6.1	NS	Zn10B1	71.67	64.41	41.28	59.12	NXZn/B(1)	4.515	12.86
	Mean	43.24	78.67	92.92	95.02					Mean	78.12	50.98	35.57	54.89	NXZn/B(2)	6.031	17.18
Straw	Zn0B0	24.01	44.83	58.87	64.43	48.03	N levels	2.41	7.408		69.69	56.87	40.83	55.8			
	Zn10B0	30.58	59.59	63.7	66.67	55.13	Zn/B	1.641	4.66								
	Zn0B1	39.74	71.45	87.25	82.91	70.34	NXZn/B(1)*	3.283	9.323								
	Zn10B1	39.14	67.32	64.91	68.2	59.89	NXZn/B(2)**	5.05	14.34								
	Mean	33.37	60.79	68.68	70.55												
Total	Zn0B0	48.13	110.3	138.9	142	109.8	N levels	3.991	12.27								
	Zn10B0	68.22	132.7	150.9	160.4	128.1	Zn/B	2.988	8.485								
	Zn0B1	91.97	155.9	193.8	189.9	157.9	NXZn/B(1)*	5.975	NS								
	Zn10B1	98.11	159	162.8	170	147.5	NXZn/B(2)**	8.635	NS								
	Mean	76.61	139.5	161.6	165.6												

* Comparison of two Zn/B levels at same level of N

**comparison of two N levels at same or different levels of Zn/B