Pak. j. life soc. Sci. (2013), 11(1): 70-76 E-ISSN: 2221-7630;P-ISSN: 1727-4915

Pakistan Journal of Life and Social Sciences

www.pjlss.edu.pk

RESEARCH ARTICLE

Agro-management Practices for Boosting Yield and Quality of Hybrid Maize (*Zea mays* L.)

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ARTICLE INFO

Received: Dec 13, 2012
Accepted: Mar 13, 2013
Online: Mar 17, 2013

Keywords

Green gram
Intercropping
Maize
Nitrogen
Zinc
Quality
Yield

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ABSTRACT

Integrated use of organic and inorganic fertilizers along with zinc application significantly augmented the yield components of maize as compared to inorganic fertilizer alone. The uses of inorganic fertilizers are very expensive, which require appropriate management to acquire economic and sustainable crop yield. Agro-management practices for boosting yield and quality of hybrid maize (*Zea mays* L.) were studied at the Agronomic Research Farm, Department of Agronomy, University of Agriculture, Faisalabad, during 2010 and 2011. The experiment comprised of two zinc levels i.e. control (no zinc application) and zinc (as zinc sulphate) at the rate of 15 kg ha^{-1}; two intercropping levels i.e. maize alone and maize + 2 rows of green gram and four nitrogen levels i.e. control (no nitrogen application), 150, 200 and 250 kg N ha^{-1}. The experiment was laid out in randomized complete block design (RCBD) with split-split plot arrangement each with three replications. Data on different growth and yield parameters of maize were recorded using standard procedures and analyzed by appropriate statistical techniques. The maximum grain rows per cob (16.10), grains per cob (524) grain weight per cob (67 g) 1000-grain weight (301 g), grain yield (6.89 t ha^{-1}), oil contents (4.46%) were observed in plots where Zn and N were applied at 15 and 250 kg ha^{-1}, respectively with 2 rows of green gram in 2010. Similar trend was recorded during 2011. Data predicted that application of zinc along with nitrogen enhanced the yield of hybrid maize. Moreover different rates of nitrogen and intercropping of green gram was useful in not only reducing reliance upon nitrogen fertilizer but also helped in reducing the net costs.

INTRODUCTION

Pakistan is a primarily an agricultural country. In spite of favorable conditions, agriculture in country suffers from under production in expression of yield per hectare. Maize ranks third among the cereal crops in the world after wheat and rice and intensively is grown on worldwide bases and often referred as “king of grain crops”. In Pakistan, it is cultivated on an area of 1.11 million hectares with an average grain yield of 3.62 Mg ha^{-1} (GOP, 2010), which is very low as compared to other maize producing countries of the world (FAO, 2004).

Crop yield and yield components are affected by diversity of factors such as poor soil fertility, scarcity of irrigation water, salinity, weeds, insects and diseases, less plant population, conventional methods and delay sowing but the imbalance nutrition application is considered the most important one (Oad et al., 2004). Nitrogen plays a dominant role in different growth process of plants, because it is an integral part of chlorophyll and pre-requisite for photosynthesis and leads to more rapid leaf area development and increase in seed yield (Akhtar et al., 2003).

Zinc deficiency problem exists in both developed as well as developing countries. According to an estimate almost fifty percent of the world’s cereal growing soils were found to be Zn deficient (Cakmak, 2002). Sillanpaa (1982) collected 3538 samples of soil and plants from 30 countries for nutrient analysis and reported that India, Lebanon, Syria, Pakistan, Turkey and Iraq are the countries where the soil Zn status was the lowest. Tandon (1991) reported that zinc application can increase yield up to 300-350 kg ha^{-1} in cereals, 300-400 kg ha^{-1} in legumes and 17 t ha^{-1} in sugarcane.

Chlorosis and white bud are symptoms of Zn deficiency in maize plants (Broadley et al., 2007).
Intercropping is the cultivation of two or more crops at the same time in the same field, which is being practiced to cover the risk of failure in base crops, cheaper source of organic fertilizer, supply balanced nutrients without compromising the sustainability of the soil to control weeds, break diseases and pests' cycles (Ibeawuchi, 2007; Zougmore et al., 2000). The use of legumes as an intercrop can serve a potential source of organic fertilizer. It can be used as a supplement source of nutrition especially that of nitrogen (Mudita et al., 2008). Maize-legumes intercropping system was found significantly better than the sole maize (Ranbir et al., 2001). In intercropping system, legumes obtain most of their nitrogen from the atmosphere and do not compete with maize in soil nitrogen. Crops such as mung bean, soybeans, cowpea and groundnuts commonly accumulate 80-250 kg N ha^{-1} (Norman, 1996). Other benefit is increase in net income due to increased yield of crops (Vesterager et al., 2008). Therefore it is obligatory that inorganic sources of nitrogen fertilizer be used in the most efficient way and only when they are necessary (Sarwar et al., 2010). Keeping this in view, the current study has, therefore, been planned to attain the subsequent objectives to identify cost effective N level for maize hybrid when intercropped with green gram, and to study the effect of N, Zn, intercropping green gram, and their interaction on the maize crop performance.

MATERIALS AND METHODS

Agro-management practices for boosting yield and quality of hybrid maize (*Zea mays* L.) were studied at the Agronomic Research Farm, Department of Agronomy, University of Agriculture Faisalabad, Pakistan during 2010 and 2011. The experimental area is located at 73 ^{0} East longitude, 31 ^{0} North latitude and at an altitude of 135 meters. Experiment comprised of two zinc levels i.e. control, no zinc application (0) and zinc sulphate at the rate of 15 kg ha^{-1} (Zn_1) in the main plot; two intercropping levels i.e. maize alone (I_0), maize + 2 rows of green gram (I_1) in sub plots and four nitrogen levels i.e. control (no nitrogen application), 150 (N_1), 200 (N_2) and 250 kg N ha^{-1}(N_3) in sub-sub plots. An experiment was laid out in randomized complete block design (RCBD) with split-split plot arrangement each with three replications. Whole nitrogen fertilizer applied in three splits i.e. 1/3 at the time of sowing, 1/3 at a plant height of 60 cm and remaining I/3 at grain formation of maize. Data on crop growth, yield and yield components, quality, competition functions, and agronomic advantages were recorded during course of study. Economic analyses was carried out to compare the economic feasibility of maize hybrid alone and intercropped with green gram.

RESULTS AND DISCUSSION

Data (Table 1) depicted that application of zinc as zinc sulphate showed non-significant effects on plant height at maturity during 2010 and 2011. Intercropping (I) showed significant effect on plant height. Significantly maximum plant height of maize (194 cm) was recorded in I_1 (maize intercropped with green gram) and minimum plant height (175 cm) was recoded in I_0 (maize alone) during 2010. Application of different levels of nitrogen showed significant effect on plant height during 2010. Significantly maximum plant height of maize (207 cm) was recorded in N_3 where N was at 250 kg ha^{-1}, which was followed by N_2 (198 cm) at 200 kg $ha^{-1}$and minimum plant height (147 cm) was recorded in control (0) where N was not applied during 2010. Similar pattern was recorded during 2011. Significantly maximum plant height of maize (220 cm) was recorded in N_3 where N was at 250 kg ha^{-1}, which was followed by N_2 (213 cm) at 200 kg $ha^{-1}$and minimum plant height (162 cm) was recorded in control (N_0) where N was not applied. These results were in conformation to the conclusion made by Chakravorty and Ibrahim et al. (2010) and Khanikar (2002) who reported that plant height increased due to sufficient supply of nutrients.
Data (Table 2) showed that soil application of zinc (as zinc sulphate), intercropping of green gram and different rates of nitrogen had a significant effect on number of grain rows per cob of maize during 2010 and 2011. Three way interactive effects of zinc, intercropping and nitrogen (Zn × I × N) were non-significant on number of grain rows per cob of maize during both the year (2010 and 2011). Significantly maximum number of grain rows per cob of maize (16.20) was recorded in $Zn_1I_1N_2$ (15 kg Zn ha^{-1} + 200 kg N ha^{-1} in maize intercropped with green gram) which was statistically at par (16.10) with $Zn_1I_1N_3$ (15 kg Zn ha^{-1} + 250 kg N ha^{-1} in maize intercropped with green gram) and minimum number of grain rows per cob (9.50) was recoded in $Zn_0I_0N_0$ (no nitrogen and zinc application, and maize was sown alone) which was statistically at par (9.90) with $Zn_1I_0N_0$ (where 15 kg ha^{-1} zinc applied in maize sown alone) during 2010. Similar trend was observed during 2011.Significantly maximum number of grain rows per cob of maize (16.10) was recorded in $Zn_1I_1N_2$ (15 kg Zn ha^{-1} + 200 kg N ha^{-1} in maize intercropped with green gram) which was statistically same (16.10) in $Zn_1I_1N_3$ (15 kg Zn ha^{-1} + 250 kg N ha^{-1} in maize intercropped with green gram) and minimum number of grain rows per cob (8.70) was recoded in $Zn_0I_0N_0$ (no nitrogen and zinc application, and maize was sown alone). These

Table 1: Effect of zinc and nitrogen on plant height (cm) of maize intercropped with green gram

Treatments	Zn_0Control				Zn_1(15 kg ha^{-1})				N (mean)	
	2010		2011		2010		2011		2010	2011
	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0 (Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)		
N_0= (Control)	137	151.00	151.67	165.67	148.33	151.67	163.00	166.33	147 D	162 C
N_1 = (150 kg N ha^{-1})	179	190.00	193.67	204.67	173.33	201.33	188.00	216.00	186 C	201 B
N_2= (200 kg N ha^{-1})	188	201.67	203.00	216.33	178.33	223.00	193.00	237.67	198 B	213 A
N_3 = (250 kg N ha^{-1})	201	210.00	216.00	224.67	193.00	223.67	201.00	238.33	207 A	220 A
Zn × I (Mean)	176 c	188.17 b	191.08	202.83	173.25 c	199.92 a	186.25	214.58		
I(Mean)	175 B	194.04A	188.67 B	208.71 A						
Zn (Mean)	183		197		187		200			
LSD Values	Year	Zn	I	Zn*I	N	Zn*N	I* N	Zn*I* N		
	2010	N.S	6.2855**	8.8890*	8.0686**	N.S	N.S	N.S		
	2011	N.S	9.6313*	13.6207	9.7609**	N.S	N.S	N.S		

Table 2: Effect of zinc and nitrogen on grain rows of maize intercropped with green gram

Treatments	Zn_0Control				Zn_1(15 kg ha^{-1})				N (mean)	
	2010		2011		2010		2011		2010	2011
	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)		
N_0= (Control)	9.50 i	10.50 gh	8.70 i	10.50 gh	9.90 hi	10.90 g	9.70 hi	10.90 fg	10.20 D	10.00 D
N_1 = (150 kg N ha^{-1})	11.30f g	11.90 f	11.30 fg	11.60 f	11.10 g	14.60 bc	11.30 fg	14.60 bc	12.20 C	12.20 C
N_2= (200 kg N ha^{-1})	12.80 e	14.60 bc	12.80 e	14.60 bc	13.40 de	16.20 a	13.40 de	16.10 a	14.30 B	14.20 B
N_3 = (250 kg N ha^{-1})	13.90 cd	15.40 ab	13.90 cd	15.40 ab	14.20 cd	16.10 a	14.20 cd	16.10 a	14.90 A	14.90 A
Zn × I (Mean)	11.90c	13.10 b	11.70 c	13.00 b	12.20 c	14.50 a	12.20 c	14.50 a		
I(Mean)	12.00 B	13.80 A	11.90 B	13.80A						
Zn (Mean)	12.50 B		12.40B		13.30 A		13.30 A			
LSD Values	Year	Zn	I	Zn*I	N	Zn*N	I* N	Zn*I* N		
	2010	0.4874*	0.3246*	0.4590*	0.4485*	N.S	0.6342*	0.8969*		
	2011	0.9153*	0.4455*	0.6301*	0.5389*	N.S	N.S	1.0777*		

results were supportive to finding of Rasool et al. (2007) and Gangwar et al. (2006) who narrated that application of zinc in maize legumes intercropping system improved grain rows of cob.

Interaction among zinc, intercropping and nitrogen (Zn×I×N) was significant on number of grains per cob of maize (Table 3). Significantly maximum number of grain rows per cob of maize (527) was recorded in $Zn_1I_1N_2$ (15 kg Zn ha^{-1} + 200 kg N ha^{-1} in maize intercropped with green gram) which was statistically at par (524) with $Zn_1I_1N_3$ (15 kg Zn ha^{-1} + 250 kg N ha^{-1} in maize intercropped with green gram) and the minimum grains per cob (303) was recoded in $Zn_0I_0N_0$ (where no zinc and nitrogen applied and maize was sown alone) which was statistically at par (312) with $Zn_1I_0N_0$ (where 15 kg ha^{-1} zinc applied in maize sown alone) during 2010. However, in 2011, the maximum number of grains per cob of maize (532) was recorded in $Zn_1I_1N_3$ (15 kg Zn ha^{-1} + 250 kg N ha^{-1} in maize intercropped with green gram) that was statistically same (532) with $Zn_1I_1N_2$ (15 kg Zn ha^{-1} + 250 kg N ha^{-1} in maize intercropped with green gram and the minimum grains per cob (271.33) was recoded in $Zn_0I_0N_0$ (no zinc application and maize was sown alone). These results have resemblance with those of Huang et al. (2007); Chahal et al. (2005); Xiang et al. (2004) and Ranbir et al. (2001).

Interaction among zinc, intercropping and nitrogen (Zn × I × N) had shown significant effect on grain weight per cob of maize (Table 4). Significantly maximum grain weight per cob of maize (67g) was recorded in $Zn_1I_1N_3$ (15 kg Zn ha^{-1} + 250 kg N ha^{-1} in maize intercropped with green gram) which was statistically at par (65 g) with $Zn_1I_1N_2$ (15 kg Zn ha^{-1} + 200 kg N ha^{-1} in maize intercropped with green gram). The minimum grain weight per cob (29 g) was recoded in $Zn_0I_0N_0$ (where no zinc and nitrogen applied in maize sown alone) during 2010. In 2011, the maximum grain weight per cob of maize (69 g) was recorded in $Zn_1I_1N_3$ (15 kg Zn ha^{-1} + 250 kg N ha^{-1} in maize intercropped with green gram) which was statistically at par (67 g) with $Zn_1I_1N_2$ (15 kg Zn ha^{-1} + 200 kg N ha^{-1} in maize intercropped with green gram). The minimum grain weight per cob (29 g) was recoded in $Zn_0I_0N_0$ (where

Table 3: Effect of zinc and nitrogen on number of grains per cob of maize intercropped with green gram

Treatments	Zn_0Control				Zn_1(15 kg ha^{-1})				N (mean)	
	2010		2011		2010		2011		2010	2011
	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)		
N_0=(Control)	303.00 j	320 hi	271 j	328 hi	312 ij	329h	321 i	338 h	316 D	315 D
N_1 =(150 kg N ha^{-1})	390g	434e	398 g	439 e	415f	456 d	424 f	464 d	424 C	432 C
N_2=(200 kg N ha^{-1})	449 d	487 c	458 d	495 c	458 d	527 a	467d	532a	480 B	488.B
N_3 =(250 kg N ha^{-1})	487 c	508 b	496c	517b	486 c	524 a	495c	533 a	502 A	510 A
Zn x I (Mean)	407 d	437 b	406	445	418 c	459 a	427	467		
I(Mean)	413 B	448 A	416 B	456 A						
Zn (Mean)	422 B		426 B		439 A		447 A			
LSD Values	Year	Zn	I	Zn*I	N	Zn*N	I* N	Zn*I* N		
	2010	7.9531*	3.0362*	4.2938*	6.3759**	9.0168*	9.0168*	12.7517*		
	2011	15.5134*	5.1321*	N.S	7.1990**	10.1810*	10.1810*	14.3981*		

Table 4: Effect of zinc and nitrogen on grain weight (g) per cob of maize intercropped with green gram

Treatments	Zn_0Control				Zn_1(15 kg ha^{-1})				N (mean)	
	2010		2011		2010		2011		2010	2011
	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)		
N_0=(Control)	29 j	36h	29 k	38 i	33 i	39 g	35 j	41 i	34.25 D	35.83 D
N_1 =(150 kg N ha^{-1})	47f	49e	49 h	55 fg	50 e	57 c	52 g	60 cd	50.58 C	53.92 C
N_2=(200 kg N ha^{-1})	54d	59 b	56ef	62 bc	57 c	65 a	59de	67a	58.75 B	60.83 B
N_3 =(250 kg N ha^{-1})	60 b	61 b	62bc	64 b	60b	67 a	62 bc	69 a	61.83 A	64.17 A
Zn × I (Mean)	47 d	51 c	49D	55 B	50 b	57 a	52 C	59A		
I(Mean)	48B	54A	50 B	56.92 A						
Zn (Mean)	49B		52 B		53.33A		51.79B			
LSD Values	Year	Zn	I	Zn*I	N	Zn*N	I* N	Zn*I* N		
	2010	2.1152*	1.1448*	1.6189*	1.1614**	N.S	N.S	2.3228*		
	2011	1.4696*	0.6848*	0.9684*	1.4174**	N.S	N.S	2.8349*		

no zinc and nitrogen applied in maize sown alone). These results were consequence to the findings of Khaliq et al. (2004); Mpairwe et al. (2002) and Jurg (2004) who reported that combination of nitrogen with zinc had significant effect on the maize crop performance.

Data (Table 5) illustrated that zinc; intercropping and nitrogen (Zn × I × N) had shown significant effect on 1000-grain weight of maize. Significantly maximum 1000-grain weight of maize (301 g) was recorded in $Zn_1I_1N_3$ (15 kg Zn ha^{-1} + 250 kg N ha^{-1} in maize intercropped with green gram) which was statistically at par (299 g) with $Zn_1I_1N_2$ (15 kg Zn ha^{-1} + 200 kg N ha^{-1} in maize intercropped with green gram). Minimum 1000-grain weight (172 g) was recoded in $Zn_0I_0N_0$ (maize was sown alone with no nitrogen and zinc application) which was statistically at par (175) with $Zn_1I_0N_0$ (maize was sown alone with 15 kg ha^{-1} zinc and no nitrogen application) during 2010. In 2011, maximum 1000-grain weight (310 g) was recorded in $Zn_1I_1N_3$ (15 kg Zn ha^{-1} + 250 kg N ha^{-1} in maize intercropped with green gram) which was statistically at par (308 g) with $Zn_1I_1N_2$ (15 kg Zn ha^{-1} + 200 kg N ha^{-1} in maize intercropped with green gram). Minimum 1000-grain weight (172 g) was recoded in $Zn_0I_0N_0$ (maize was sown alone with no nitrogen and zinc sulphate application). Data in the table also indicated that application of 15 kg Zn ha^{-1} + 250 kg N ha^{-1} in maize intercropped with green gram produced 75 % more yield during 2010 and 79% in 2011 as compared to control. These results were supportive to finding of Obrador et al. (2003) who reported that improvement in 1000-grain weight of maize is due to timely and balanced application of zinc and nitrogen to maize crop when intercropped with green gram.

Significant effect of interaction among zinc, intercropping and nitrogen (Zn × I × N) was found on grain yield of maize (Table 6). Significantly maximum grain yield of maize (6.89 t ha^{-1}) was recorded where 15 kg ha^{-1} zinc and 250 kg ha^{-1} nitrogen applied in maize intercropped with green gram which was statistically at par (6.83 t ha^{-1}) with where 15 kg ha^{-1} zinc and 200 kg ha^{-1} nitrogen applied in maize intercropped with green gram. The minimum grain

Table 5: Effect of zinc and nitrogen on 1000-grains weight (g) of maize intercropped with green gram

Treatments	Zn_0 Control				Zn_1 (15 kg ha^{-1})				N (mean)	
	2010		2011		2010		2011		2010	2011
	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)		
N_0=(Control)	172 j	190 i	172 k	198 i	175 j	198h	183 j	206.h	184 D	190 D
N_1 =(150 kg N ha^{-1})	255 g	270 e	263 g	278 de	261f	278cd	269fg	287 c	266 C	275 C
N_2=(200 kg N ha^{-1})	267 e	281 c	275 ef	290 c	269 e	299 a	277e	308 ab	279 B	288 B
N_3 =(250 kg N ha^{-1})	276 d	294 b	284 cd	302 b	280 cd	301 a	28 c	310 a	288 A	296 A
Zn x I (Mean)	243 D	259 B	249 C	267 A	246C	269A	254	278		
I(Mean)	244 B	264 A	252 B	272 A						
Zn (Mean)	251 B		258 B		258 A		266 A			
LSD Values	Year	Zn	I	Zn*I	N	Zn*N	I* N	Zn*I* N		
	2010	3.4241*	1.5624*	2.2096*	2.2133*	N.S	3.1301*	4.4266*		
	2011	3.1176*	4.1877*	N.S	3.3492*	N.S	N.S	6.6984*		

Table 6: Effect of zinc and nitrogen on grain yield (t ha^{-1}) of maize intercropped with green gram

Treatments	Zn_0 Control				Zn_1 (15 kg ha^{-1})				N (mean)	
	2010		2011		2010		2011		2010	2011
	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)		
N_0=(Control)	2.48 h	2.68 fg	2.49 i	2.78 gh	2.63 gh	2.84 f	2.64 hi	2.94 g	2.66 D	2.71 D
N_1 =(150 kg N ha^{-1})	4.22 e	4.52 s	4.32 f	4.62 e	4.34 de	5.30 c	4.44 ef	5.37 d	4.59 C	4.69 C
N_2=(200 kg N ha^{-1})	5.31 c	5.71 b	5.41 d	5.81 c	5.30 c	6.83 a	5.40 d	6.75 a	5.79 B	5.84 B
N_3 =(250 kg N ha^{-1})	5.40 c	5.90 b	5.50 c	6.00 b	5.39 c	6.89 a	5.49 d	6.79 a	5.89 A	5.95 A
Zn x I (Mean)	4.35 c	4.70 b	4.43 c	4.80 b	4.41 c	5.47 a	4.49 c	5.46 a		
I(Mean)	4.38 B	5.08 A	4.46 B	5.13 A						
Zn (Mean)	4.53 B		4.62 B		4.94 A		4.98 A			
LSD Values	Year	Zn	I	Zn*I	N	Zn*N	I* N	Zn*I* N		
	2010	0.0669*	0.0998**	0.1411*	0.0961**	0.1359*	0.1359*	0.1921*		
	2011	0.1061*	0.0760*	0.1075*	0.0904**	0.1278*	0.1278*	0.1807*		

yield (2.48 t ha^{-1}) was recoded in control plots where maize was sown alone during 2010. However, in 2011 maximum grain yield of maize (6.79 t ha^{-1}) was recorded in $Zn_1I_1N_3$ (15 kg Zn ha^{-1} + 250 kg N ha^{-1} in maize intercropped with green gram) that was statistically same (6.75 t ha^{-1}) with $Zn_1I_1N_2$ (15 kg Zn ha^{-1} + 200 kg N ha^{-1} applied in maize intercropped with green gram. The minimum grain yield (2.49 t ha^{-1}) was recoded in $Zn_0I_0N_0$ (maize was sown alone with no nitrogen and zinc sulphate application). Data also narrated that application of 15 kg Zn ha^{-1} + 250 kg N ha^{-1} in maize intercropped with green gram increased 177% grain yield during 2010 and 172% in 2011 as compared to control. These results were in conformation to the conclusion made by Khan et al. (2005), Khaliq et al. (2004) and Sims et al. (1995) who reported that different rates of nitrogen and zinc improved the maize yield.

Three way interactions of zinc, intercropping and nitrogen (Zn × I × N) had shown a pronounced effect on oil contents of maize (Table 7). Maximum grain oil contents of maize (4.46 %) was recorded in $Zn_1I_1N_3$ (where 15 kg ha^{-1} zinc and 250 kg ha^{-1} nitrogen applied in maize intercropped with green gram) and the minimum grain oil contents (2.55 %) was recoded in $Zn_0I_0N_0$ (where no zinc and nitrogen applied in maize sown alone) during 2010. A similar trend was observed during 2011. Data illustrated that application of 15 kg ha^{-1} zinc and 250 kg ha^{-1} nitrogen applied in maize intercropped with green gram increased 74% grain oil contents during 2010 and 2011 as compared to control. These results were in conformation to the conclusion made by Oktem and Oktem (2005) Kumar et al. (2005) who reported that different rates of nitrogen and zinc enhanced the oil contents.

Interactive effect of zinc, intercropping and nitrogen (Zn × I × N) had been recorded significantly in case of protein contents of maize (Table 8). Maximum protein contents of maize (9.18 %) was recorded in $Zn_1I_1N_3$ (where 15 kg ha^{-1} zinc and 250 kg ha^{-1} nitrogen applied in maize intercropped with green gram) and minimum protein contents (4.67 %) was recoded in $Zn_0I_0N_0$

Table 7: Effect of zinc and nitrogen on oil % of maize intercropped with green gram

Treatments	Zn_0Control				Zn_1(15 kg ha^{-1})				N (mean)	
	2010		2011		2010		2011		2010	2011
	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)		
N_0= (Control)	2.55 j	2.67 ij	2.58 k	2.73 j	2.59 ij	2.67 i	2.75 j	2.70 j	2.62 D	2.69 D
N_1 = (150 kg N ha^{-1})	2.58 ij	3.32 g	3.31 i	3.38 h	3.29 gh	3.75 f	3.35 hi	3.81 g	3.23 C	3.46 C
N_2= (200 kg N ha^{-1})	3.18 h	4.08 d	3.91 f	4.14 d	3.94 e	4.28 b	4.00 e	4.34 b	3.87 B	4.10 B
N_3 = (250 kg N ha^{-1})	4.15 cd	4.27 b	4.21 c	4.34 b	4.23 bc	4.46 a	4.29 b	4.49 a	4.28 A	4.33 A
Zn × I (Mean)	3.12	3.59	3.50	3.65	3.51	3.79	3.60	3.84		
I(Mean)	3.31 B	3.69 A	3.55 B	3.74 A						
Zn (Mean)	3.35 B		3.58 B		3.65 A		3.72A			
LSD Values	Year	Zn	I	Zn*I	N	Zn*N	I* N	Zn*I* N		
	2010	0.1191*	0.1156**	N.S	0.0584**	0.0826*	0.0826*	0.1168*		
	2011	0.1038*	0.0556*	N.S	0.0928**	N.S	0.1313	0.1857*		

Table 8: Effect of zinc and nitrogen on protein % of maize intercropped with green gram

Treatments	Zn_0Control				Zn_1(15 kg ha^{-1})				N (mean)	
	2010		2011		2010		2011		2010	2011
	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)	I_0(Maize alone)	I_1(Maize + 2 rows of green gram)		
N_0= (Control)	4.67 j	4.75 j	4.56 m	4.75 l	4.83 ij	4.95 i	4.83 kl	4.95 k	4.80 D	4.77 D
N_1 = (150 kg N ha^{-1})	6.97 h	7.24 g	6.97 j	7.24 i	7.32 g	7.48 f	7.32 i	7.45 h	7.26 C	7.25 C
N_2= (200 kg N ha^{-1})	7.86 e	8.32 d	7.89 g	8.32 e	8.05 e	8.64 b	8.05 f	8.64 b	8.22 B	8.22 B
N_3 = (250 kg N ha^{-1})	8.38 cd	8.48 bcd	8.38 de	8.48 cd	8.56 bc	9.18 a	8.56 bc	8.77 a	8.65 A	8.55 A
Zn × I (Mean)	6.97	7.20	6.95	7.20	7.19	7.56	7.19	7.45		
I(Mean)	7.08 B	7.42 A	7.07 B	7.32 A						
Zn (Mean)	7.11 B		7.07 B		7.38 A		7.32A			
LSD Values	Year	Zn	I	Zn*I	N	Zn*N	I* N	Zn*I* N		
	2010	0.1152*	0.1391*	N.S	0.0975**	N.S	N.S	0.1951*		
	2011	0.0795*	0.0432**	N.S	0.0590**	N.S	0.0834*	0.1180*		

(where no zinc and nitrogen applied in maize sown alone) during 2010. Same trend was recorded during 2011. Data also illustrated that 15 kg ha^{-1} zinc and 250 kg ha^{-1} nitrogen applied in maize intercropped with green gram increased 96% grain protein contents during 2010 and 92% during 2011 as compared to control. These results were in conformation to the conclusion made by Huang et al. (2007) and Gangwar et al. (2006) who noted that adequate nitrogen promoted vigorous growth and dark green colour, a constituent of all proteins and enzymes.

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